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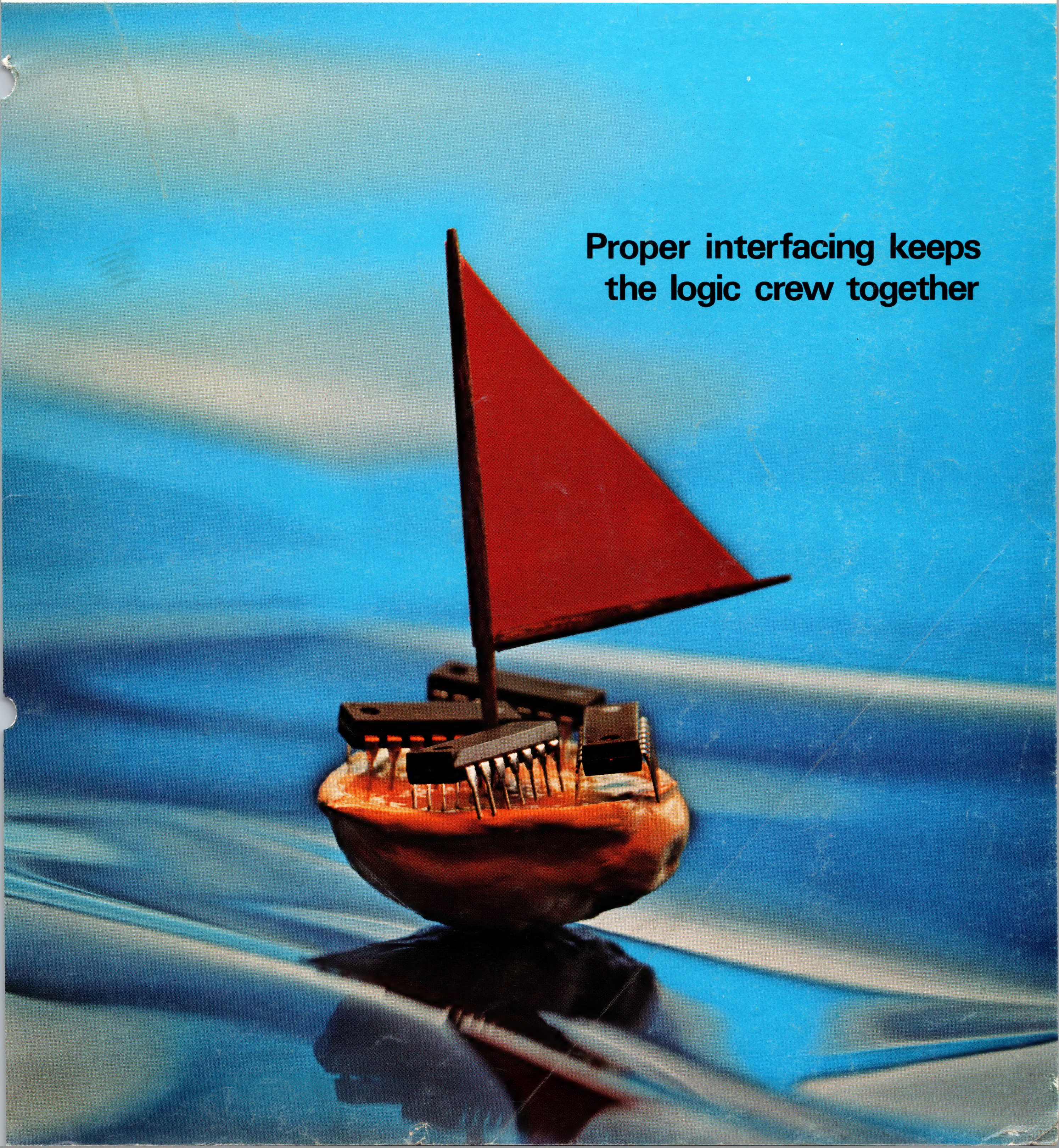
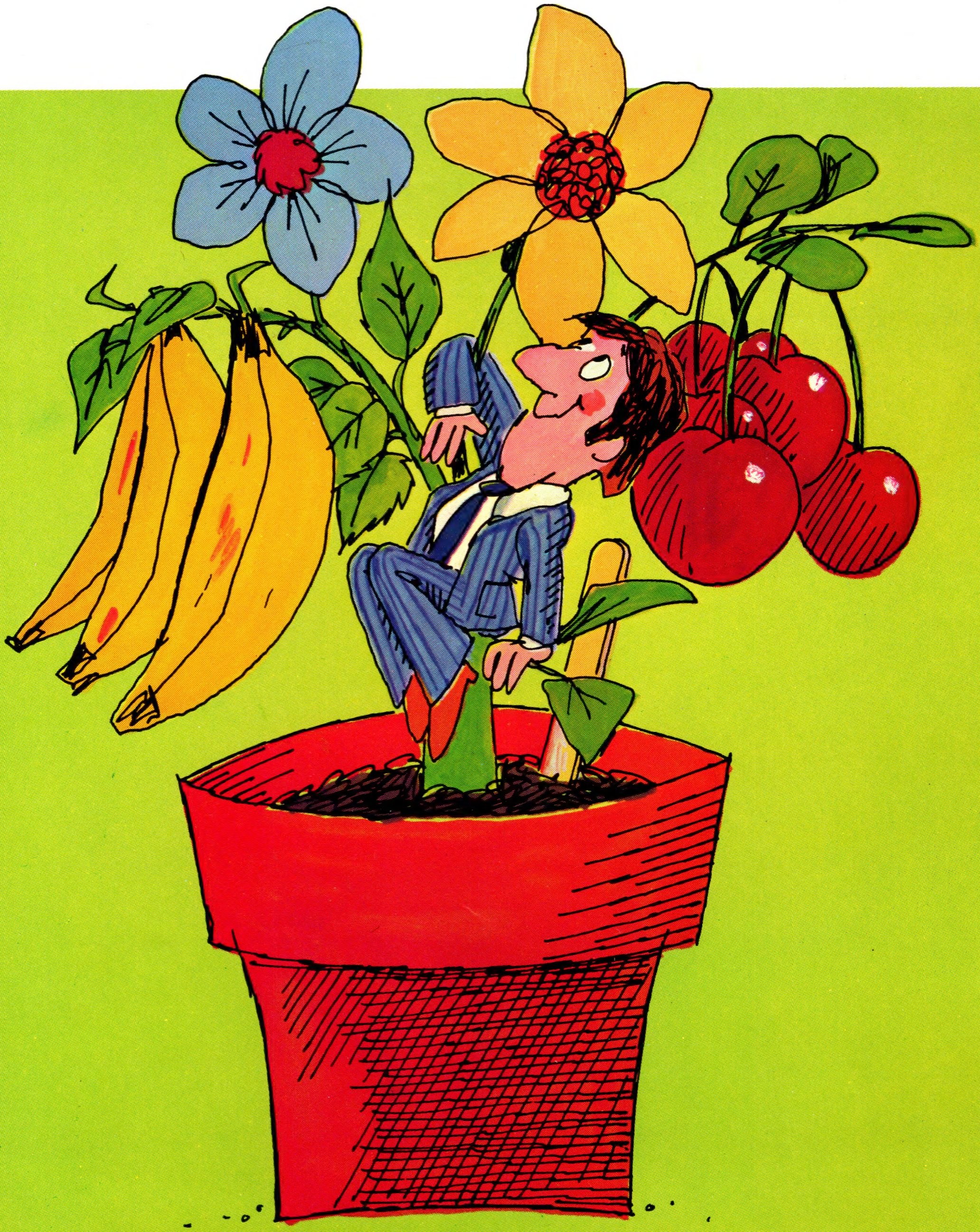


Proper interfacing keeps the logic crew together



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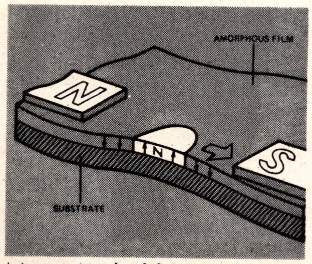

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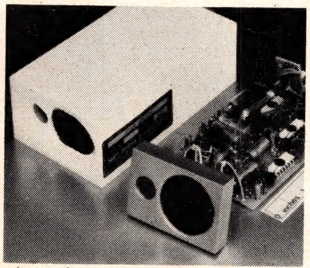

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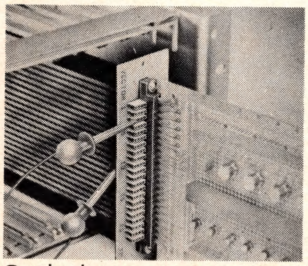

Card adapter . . . . . . pg. 53

COVER

Squeezing the optimum logic mix into your system isn't easy. For smooth sailing, differing logic families must be buffered properly. National Semiconductor, Santa Clara, CA provided our clever and colorful cover photo. CMOS voltage translation / buffering story begins on pg. 24.

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DESIGN FEATURES

PROGRESS IN PRODUCTS

DESIGN PRODUCTS

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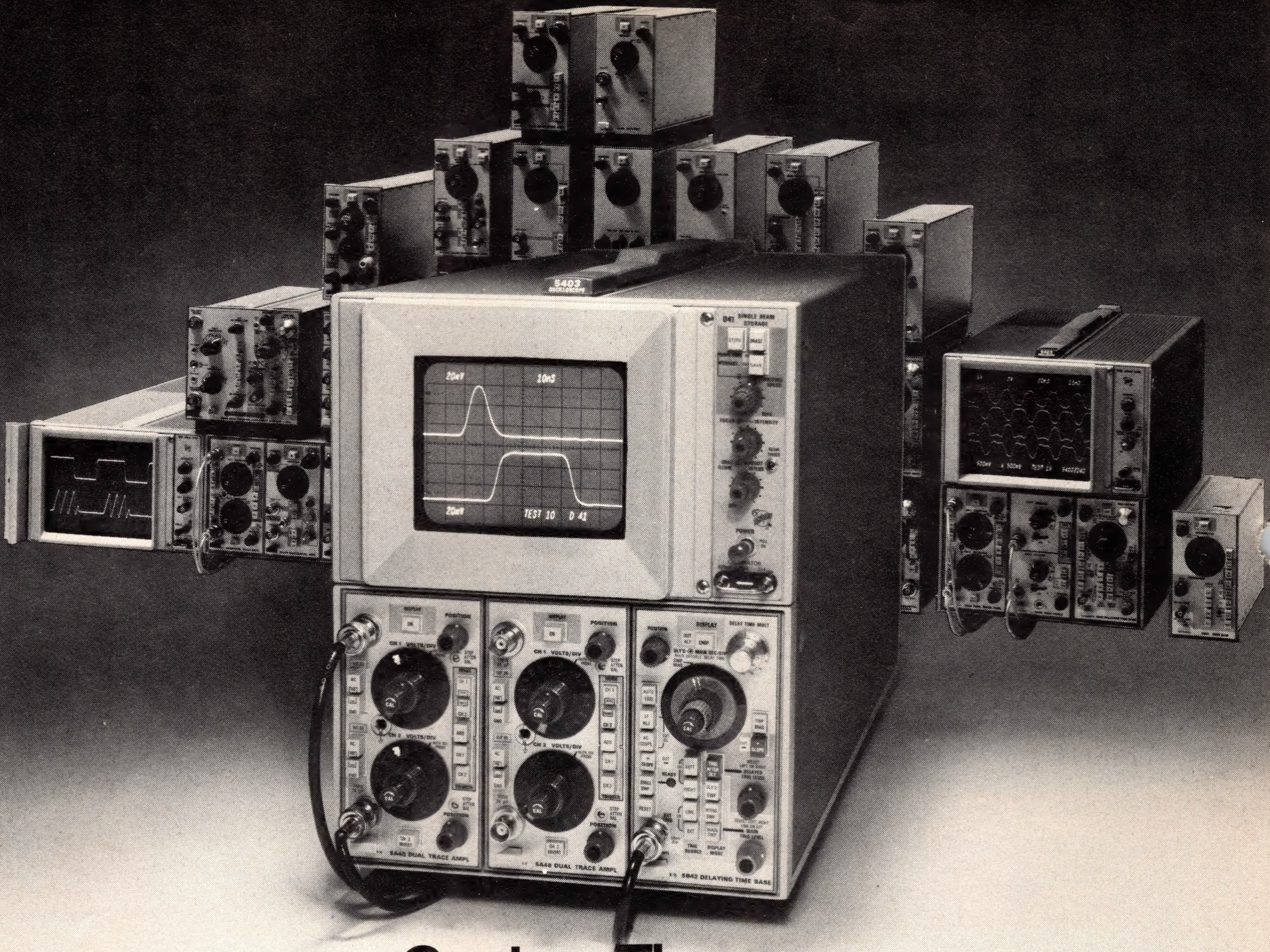

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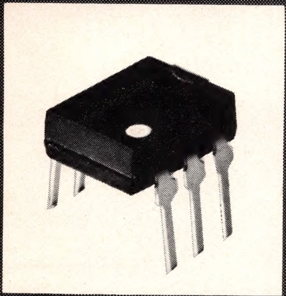

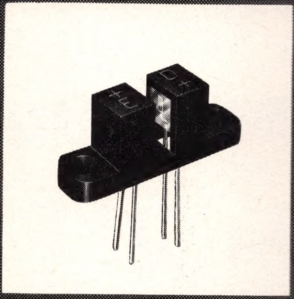

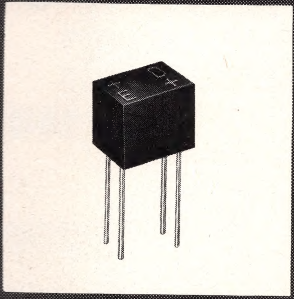

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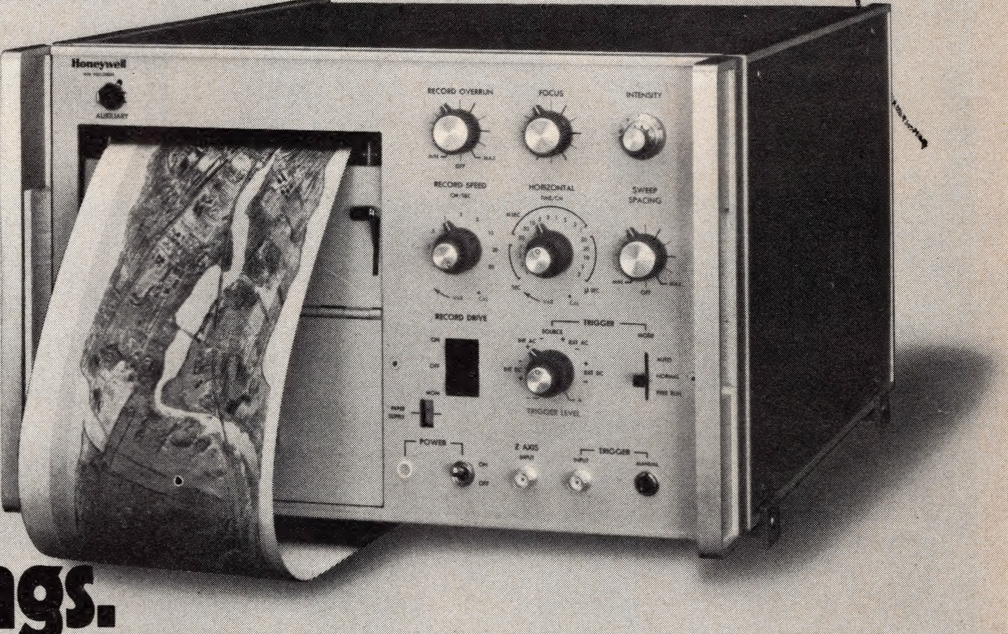

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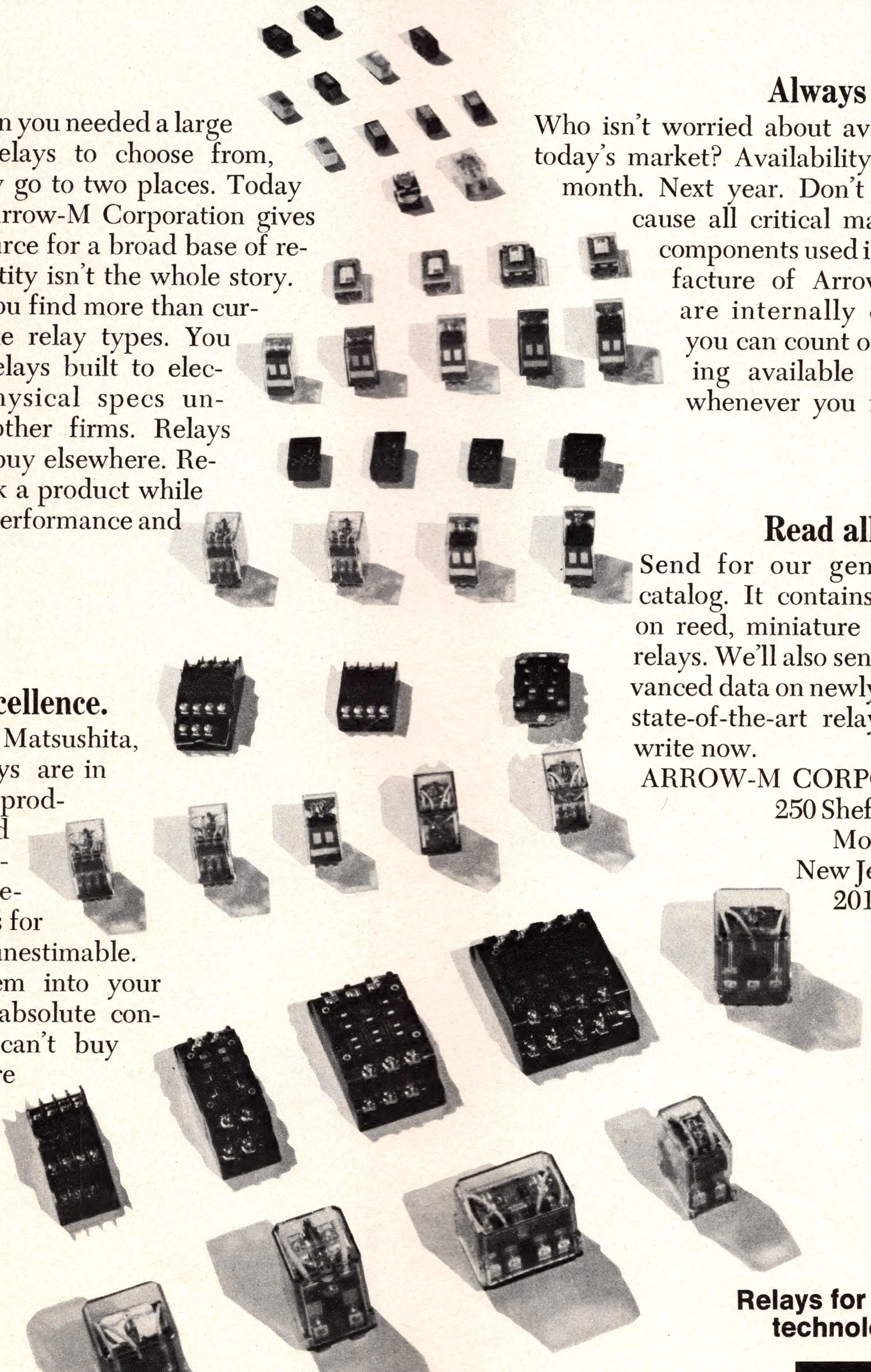

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Tis the season to be jolly?

With things being as they are right now—high inflation, reduced opportunities in the electronics business, layoffs of engineers, etc.—it's downright difficult to be jolly. However, this is the biggest holiday season of the year, and we can all use a break from our everyday problems and pressures.

In view of this I am making this editorial short and to the point. Merry Christmas! Happy Chanukah! Happy New Year! Additionally, I prescribe no less than six ounces of merriment for each and all. And if you need something to occupy your mind, try this:

$$\{EY[M(X-A)(X+A)+A^2M]\}\left\{\frac{\frac{R+X}{X}+\frac{X}{R-X}}{\frac{X}{R-X}}-\left[\frac{4AS}{3Y\{(X+E)^2-(X-E)^2\}}+\frac{4AS}{3E\{(X+Y)^2-(X-Y)^2\}}+\frac{4AS}{3X\{(E+Y)^2-(E-Y)^2\}}\right]\right\}$$

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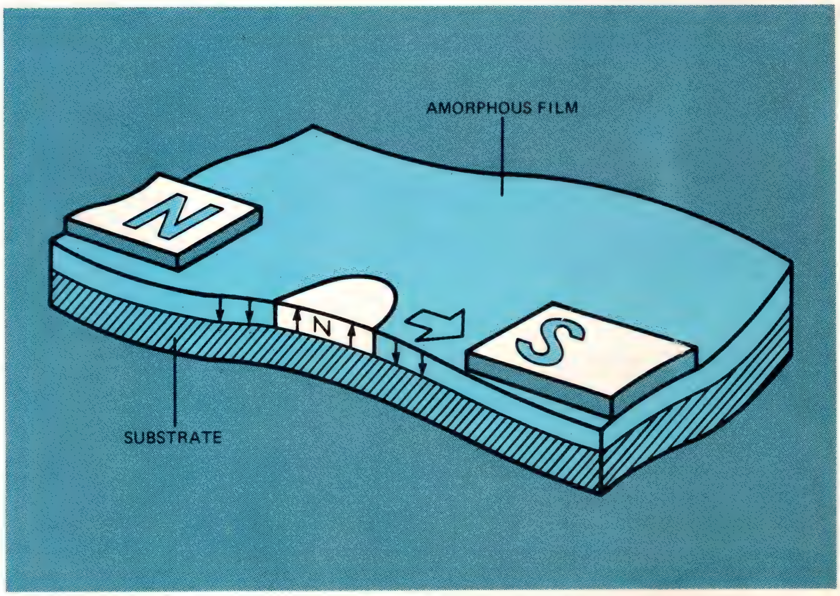
Magnetic bubbles observed in evaporated amorphous films

Magnetic bubbles have been reported, for the first time, in amorphous thin-film alloys made by conventional evaporation techniques. Drs. Neil Heiman and Kenneth Lee, of IBM's San Jose Research Laboratory, prepared the films as part of a project aimed at reaching a better understanding of magnetism in amorphous materials.

The new magnetic bubble materials are the alloys holmium-colbalt, holmium-nickel and holmium-iron. These films, all about 1000 angstroms thick, support magnetic bubbles of comparable diameters under favorable conditions of temperature and alloy composition. Prior to this work, no amorphous material made by evaporation had been reported as a medium for magnetic bubbles.



Bubble circuits fabricated with amorphous films look and operate basically the same as crystalline films. The cutaway diagram shows a magnetic "bubble" moving in the amorphous film between overhead circuit elements. Pioneering work on this subject is being done at IBM's Thomas J. Watson Research Center and San Jose Research Laboratory.

Fabrication much easier

The surprising discovery that amorphous materials could support bubbles was first reported by scientists at the IBM Thomas J. Watston Research Center in early 1973. This demonstration opened up new opportunities for developing the bubble technology. To date, the most frequently used method of preparing amorphous magnetic bubble films has been sputtering. The main difference between sputtering and evaporation is the way in which the atoms are obtained and deposited to form the alloy film.

In the sputtering process, groups of atoms are chipped away electrically from the surface of a target material having the same composition as that of the desired alloy film. As atoms are knocked off the target, they fall onto a substrate, building up the layers of an alloy film.

To produce sputtered films capable of supporting magnetic bubbles, a small "bias" voltage is applied to the substrate. This causes atoms arriving at the substrate to dislodge some of the atoms already attached to the film. These atoms are rearranged in such a way that their atomic spins become aligned perpendicular to the film surface. The physical property thus imparted to the film, uniaxial anisotrophy, is a necessary condition for generating bubbles.

In the evaporation process, alloys are formed when beams of thermally agitated atoms

intermingle and condense on the underside of a substrate that is suspended in their paths. Each beam rises, like steam from a tea spout, from a heated dish containing, in liquid form, one of the elements of which the alloy is composed.

The proportion of each element in the film is rather easy to control, depending mainly on the temperature to which the sample is heated and the distance between the samples and the substrate.

A step forward?

Much simpler than "sputtering," evaporation may offer new flexibility and economy in the fabrication of magnetic bubble materials.

The great advantage of evaporation, says Dr. Lee, is that "it eliminates the trouble and expense of making a target for sputtering. It is difficult to obtain a target having the same proportion of elements throughout its entire volume. Once a target has been chosen, there is not much flexibility left in the process to vary the composition of alloy films."

"Of course," he continues, "the value of evaporation for making magnetic bubble materials depends on the quality of the end product. And so far, the superiority of evaporated bubble films has not been proven conclusively."—*TO*

Composite material interconverts magnetic and electrical signals

The interconversion of electrical and magnetic fields is well known. For example, a solenoid achieves it. Homogeneous magneto-electric materials are also well known—chromium sesquioxide (Cr_2O_3) being the best of these at room temperatures.

How, then, can a new composite material developed at the Philips Research Laboratories, Eindhoven, The Netherlands, be called a breakthrough? Because in the new material, which consists of a piezomagnetic and a piezoelectric component, the conversion is brought about by mechanical deformation.

Boosting the output

The unique nature of this conversion mechanism is fortuitous, because it means that the degree of conversion is optimum at the frequency at which the material exhibits mechanical resonance. Therefore, when the composite is allowed to resonate mechanically, the mechanical quality factor ($Q \approx 400$) increases the output signal.

The new magneto-electric composite can be used where electrical and magnetic fields require interconversion at frequencies above 3 Hz. This limiting frequency is determined

	$\frac{dP}{dH}\left(\frac{C}{cm^2 Oe}\right)$	ϵ_{rel}	$\frac{dE}{dH}\left(\frac{V}{cm \cdot Oe}\right)$	$\frac{dM}{dE}\left(\frac{Gauss \cdot cm}{V}\right)$	H_{bias} (Oe)
Cr_2O_3	2.1×10^{-14}	12	2.0×10^{-2}	2.6×10^{-6}	–
COMPOSITE	2.9×10^{-12}	700	5.5×10^{-2}	3.7×10^{-4}	750
	1.9×10^{-12}		3.5×10^{-2}	2.3×10^{-4}	0

Magneto-electric properties of the new 3-phase composite material are compared here to chromium sesquioxide.

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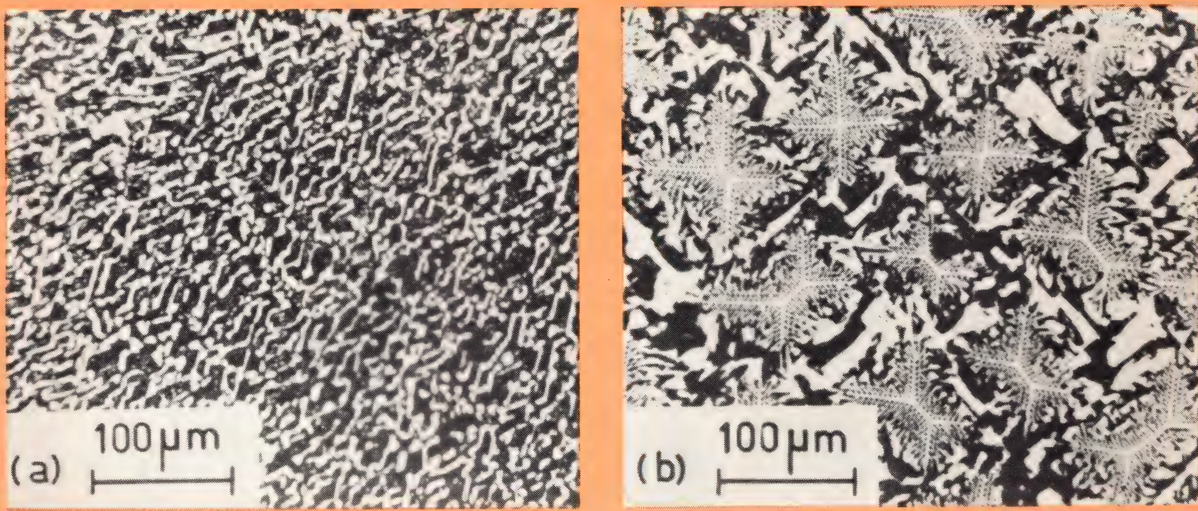

Fig. 1—Mechanical deformation triggers the interconversion process in these unique new magneto-electric composites developed by Philips Research Laboratories, Eindhoven, The Netherlands. **Fig. 1a** shows the 2-phase composite; **Fig. 1b**, the 3-phase material. In both cross-sections, the darker component is the piezoelectric material; the lighter, the piezomagnetic.

by the electrical conductivity of the composite material.

2ϕ and 3ϕ materials

Responsible for the idea which led to the development is J. Van Suchtelen, of the Philips staff. He had the idea that it should be possible to interconvert the two fields in a composite material grown in situ and consisting of a piezomagnetic and a piezoelectric component. Such a material was therefore made in the laboratory by J. van den Boomgaard and A. M. J. G. van Run. They allowed a molten eutectic mixture of barium titanate and cobalt ferrite to solidify unidirectionally.

Structure of the composite, which is obtained as small rods with a diameter of 4 mm, is shown in **Fig. 1a**. Other components also were included in the investigation. Furthermore, similar composites were produced by allowing melts of a composition differing from the eutectic (e.g., by adding an excess of TiO_2) to solidify unidirectionally, so that 3-phase composites were also produced (**Fig. 1b**).

The table shows a comparison of the magneto-electric properties of the composite material of **Fig. 1b** with those of chromium sesquioxide. However, the results described refer to laboratory experiments, only. They do not necessarily imply a follow-up in production or marketing.—*WP*

EDN's Fourth Annual Creative Design Contest

EDN is proud to sponsor another creative design contest. Basic guidelines for qualified entries remain the same as in past contests. All entries will be judged on the following: technical competence and utility, creative imagination and—most importantly—the number of products advertised in the January 5 and 20 issues that are used in your design.

Contest rules also remain unchanged. All designs should be consumer oriented; that is, they should be applicable in or around the home, auto or recreational vehicle. Circuits must be submitted exclusively to EDN, must be original with the entrant(s), must not have been published previously (limited distribution house organs excepted), and must have been constructed and tested. Last year's winners are not qualified to win this year.

Grand prize is a Heathkit Model GR-2000 digital-design color TV. It features 25-in. picture tube, varactor solid-state tuning, on-screen channel and time display, up to 16 programmable channels, remote control and choice of cabinet styles. Retail value—$945. Nine other exciting prizes will be awarded to runners-up.

Watch for the entry blank and full set of rules in EDN's January 5, 1975 issue. Enter early!—*WP*

1975

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We may be visiting your city—or perhaps your own plant site.
Watch for the detailed tour schedule in our next issue.

DESIGN FEATURES

Infrared: an expanding and diverse technology

In the future, you may do most of your electronic testing with IR. Are you ready for that?

Erwin Vodovoz, West Coast Editor

What comes to mind when you hear the word "infrared"? Most engineers would say "IR or heat seeking missles" or perhaps "devices that enable you to see in the dark." While these two areas of IR involvement are important, they are like the visible 10% of the iceberg. The other 90% is out of sight (slight pun). So broad is the subject that a close look at it all is impossible. However, we hope that a look at the following selected material will stimulate a connection betweeen your problems and an infrared solution.

The absorption spectrum **(Fig. 1)** is of great importance when transmitting or sensing with IR. These absorption characteristics are used to detect the constituent parts of smog. They also provide a valuable source of information from weather satellites.

Stopping an explosion!

A dramatic example of an IR system's capability is the fire sensor designed by the Santa Barbara Research Center, a subsidiary of Hughes Aircraft Co. This system detects the start of an explosion in 1.5 msec and releases Freon^R into the area to smother the fire and explosion. It all happens in about 80 msec, fast enough to prevent the explosion from really getting started.

Shown in **Fig. 2** is the dual range fire sensor,

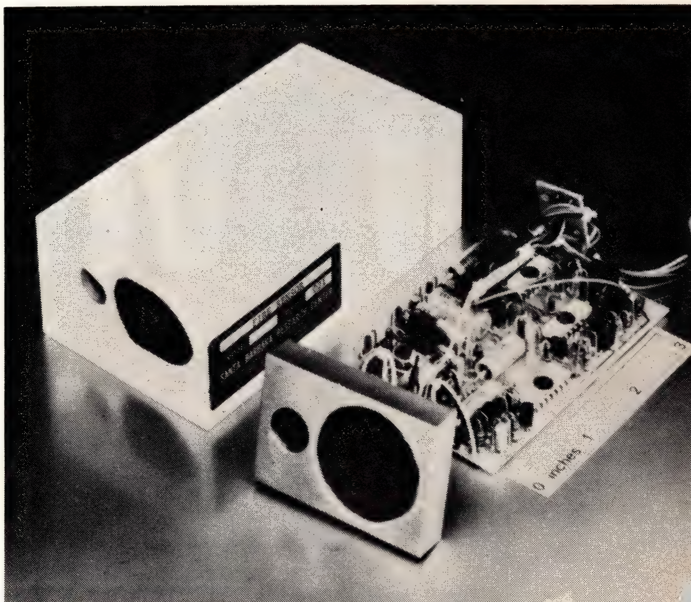


Fig. 2—Fire detectors' excellent performance is attributed to using dual range sensors. Located behind the two circular windows are the sensors for the 0.6 to 0.9 μm and 7 to 30 μm bands.

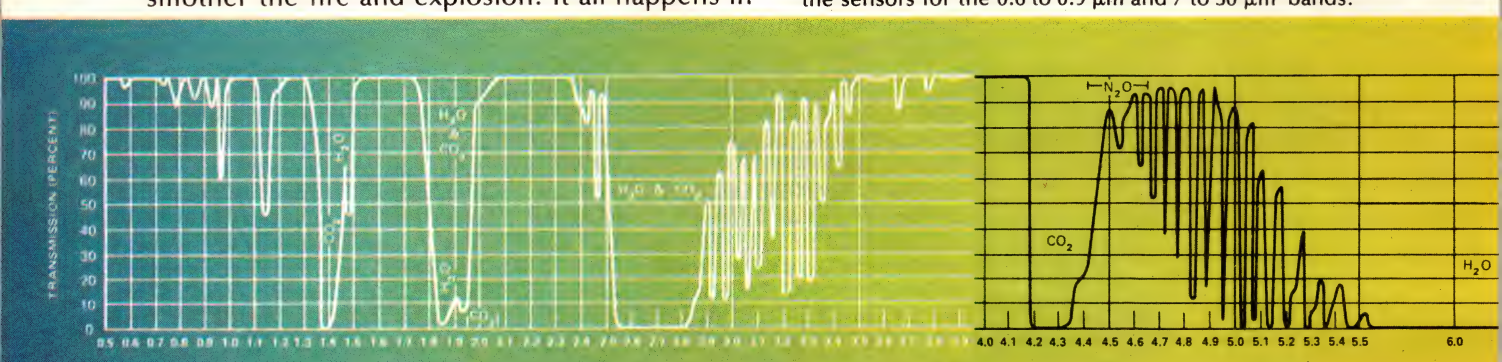


Fig. 1—Transmission spectrum of IR from 0.5 to 25.0 μm indicates the level of absorption due to H_20, N_2O, and CO_2.

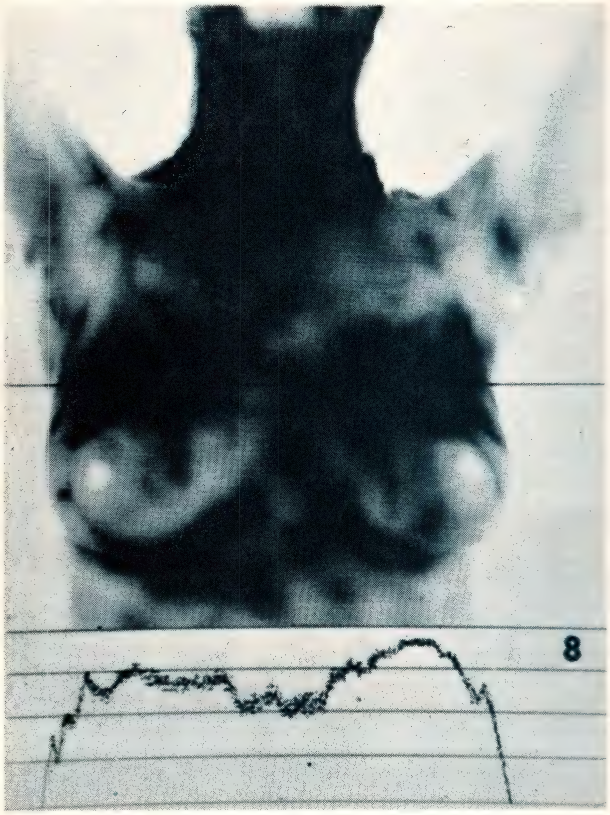


Fig. 3—Passive breast cancer detection is a working reality. Graph at the bottom is the temperature correspondence for the scan line across the breasts. Cancer of the left breast is indicated by the higher temperature (approximately 1.5°C) and the darker density venous pattern.

model PM-3WT. To prevent false alarms, two IR bands are monitored, 0.6 to 0.9 μm and 7 to 30 μm. By sensing two bands, energy must be present in the ranges of light and heat before the Freon[R] is released. This prevents false alarms from sunlight, lighted matches (as close as a foot away), and other normal lighting, including reflected light and light chopped at high and low frequencies. In fact, in tests judged to be equivalent to seven years of actual use, no false alarms occurred.

The military prompted the development of this system since most deaths in tanks and troop carriers are due to fire and explosion of the fuel system. In actual tests, 3.5-in. high energy antitank heat rounds were fired into the fuel tank of a personnel carrier, the M-113. The system response time was fast enough to prevent injury to any occupant (assuming the shells do not hit the crew).

A star is born

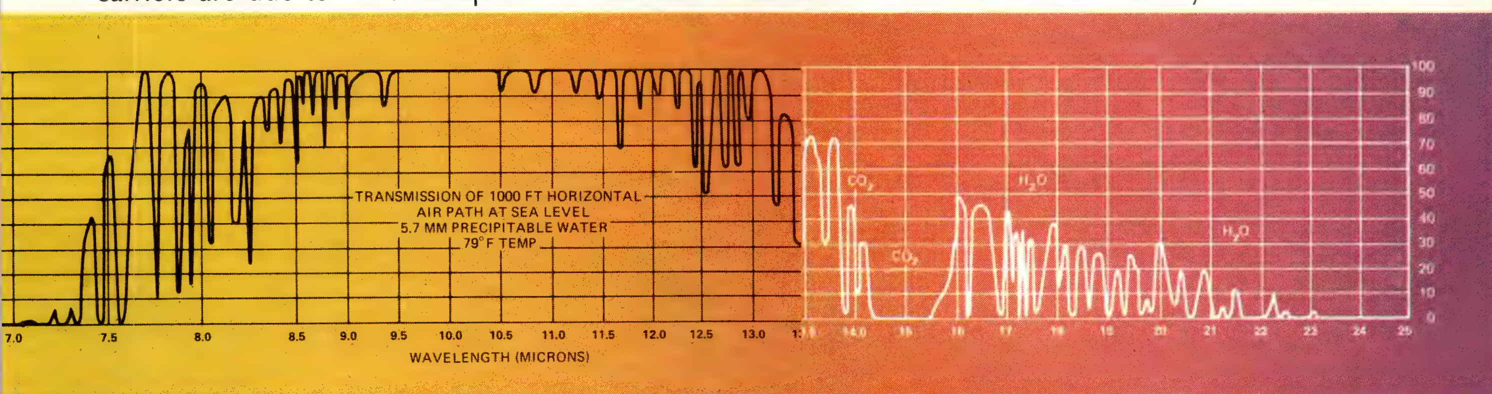
Well, actually, five stars were born. These recently discovered and invisible stars can be detected only by infrared means. They are young as stars go, less than 100,000 years old. Located in the great nebula of Orion, they are relatively close at a distance of 1600 light years.

Standard procedure when measuring the heat from a visible star is to turn the telescope (and attached IR sensors) slightly to measure the heat from the colder sky background. The true heat radiation from the star equals the difference between the two readings. When Ian Gatley, a graduate student at the California Institute of Technology, and Dr. Michel Penston of Britain's Royal Greenwich Observatory attempted to do this, the temperature reading went up, instead of down. They had stumbled across an invisible IR-emitting star. The 4-month search that followed led to the detection of four more invisible stars.

This discovery is the second group of embryo stars in the Orion Nebula. The first group was found by infrared astronomers at the Hale Observatories and the University of Arizona. These two findings help to solidify the theories of star formation.

Are X-ray's a tool of the past?

Not yet, but it may happen. It seems that the more we learn about X-ray's, the lower we set the limits for safe exposure. That limit could conceivably go to zero. As a medical diagnostic tool, thermography (thermal imaging) may well replace X-ray's. In particular, thermography has become the preferred examination tool for the detection of breast cancer **(Fig. 3)**. A passive system, it detects the heat emitted from a body. Since there



Detection of these gases depends upon selection of the proper frequency. *(Santa Barbara Research Center)*

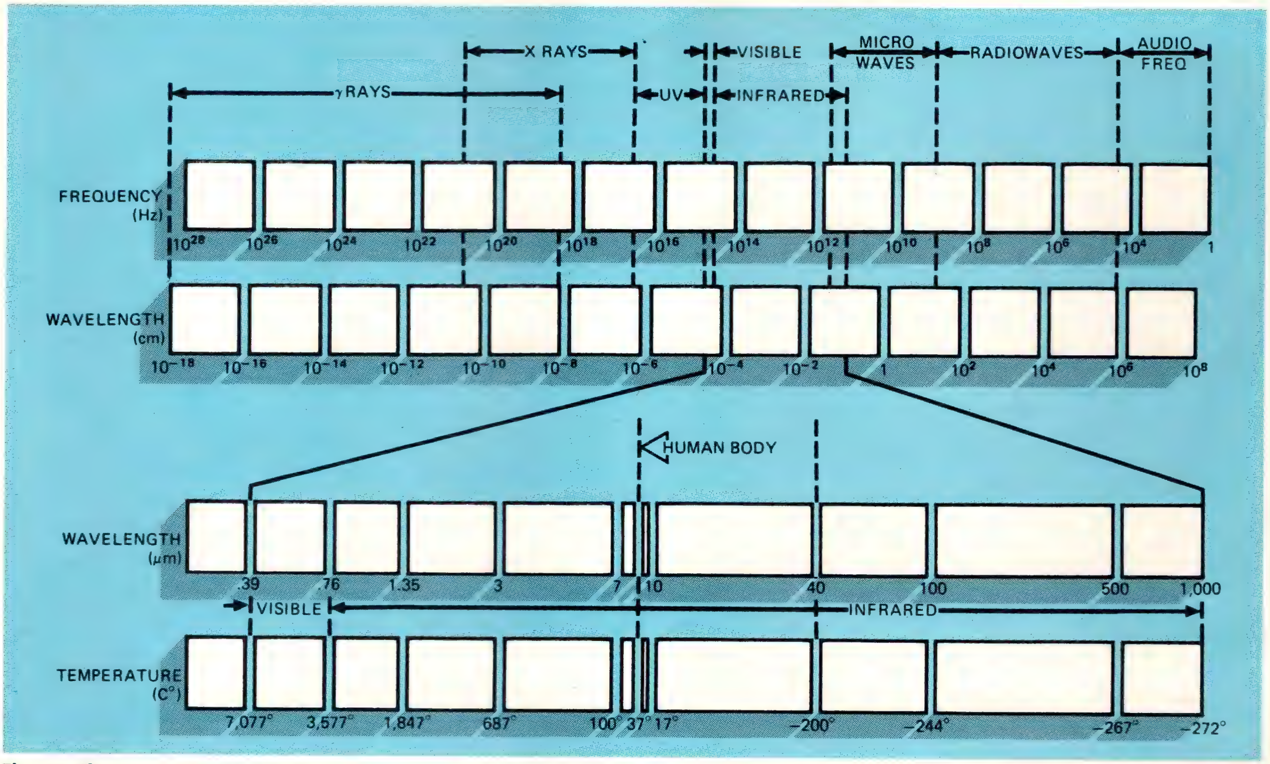


Fig. 4—Electromagnetic spectrum displays overlapping area of IR and microwaves. Note the temperature corresponding to the peak of the IR radiation.

is no exposure to X-ray's, a thermograph can be taken as often as required with no ill effect.

For the three diverse systems just described, the common denominator is obvious—infrared. Therefore, let's backtrack and cover some basic IR concepts to see what makes the technology so useful.

The ABC's of IR

Molecular motion within any object generates IR radiation. Therefore, any object with a temperature above absolute zero is an IR radiator. The energy radiated by a body contains many frequencies, but reaches a maximum at only one wavelength. As the temperature of the body increases, the peak moves toward shorter wavelengths. Total emitted radiation is a function of the absolute temperature and the radiating area.

Fig. 4 shows the electromagnetic spectrum and infrared location within that spectrum. Engineers working in IR refer to "near IR," "far IR," "intermediate IR," "middle IR," and "extreme IR." There is no standard for these terms. As IR detectors improve and IR systems move into the longer IR wavelengths, the dividing lines for "far IR," "middle IR," and so on also move.

As can be seen from **Fig. 4**, IR extends from the microwave region on up into the region of light. Likewise, it exhibits the characteristics of both light and microwaves. Therefore, applications can take advantage of both effects.

A well kept secret

When it comes to detectors, there seem to be as many types as there are frequencies. Major groupings include the thermal (thermometers, bolometers), chemical (film), and quantum (semiconductor) types. Selection of the optimum

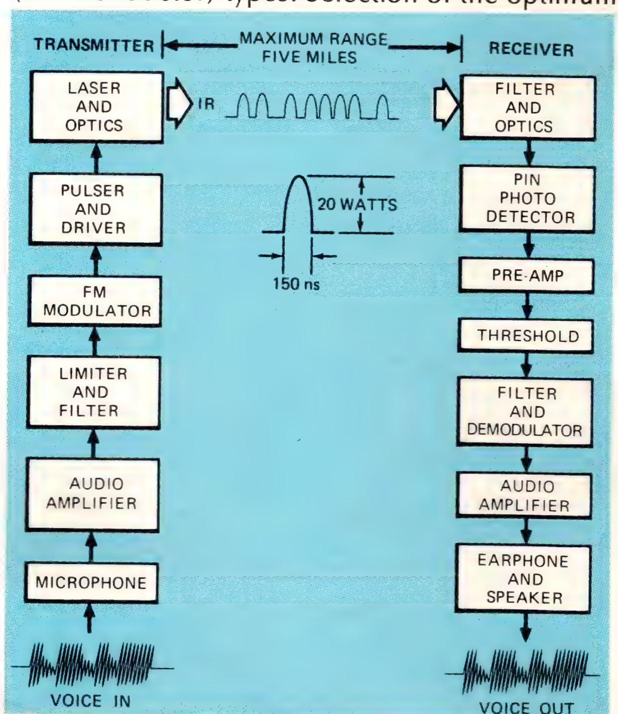


Fig. 5—IR laser makes possible this secure communication system. Features include nondetectable transmission and full duplex operation in a portable lightweight design.

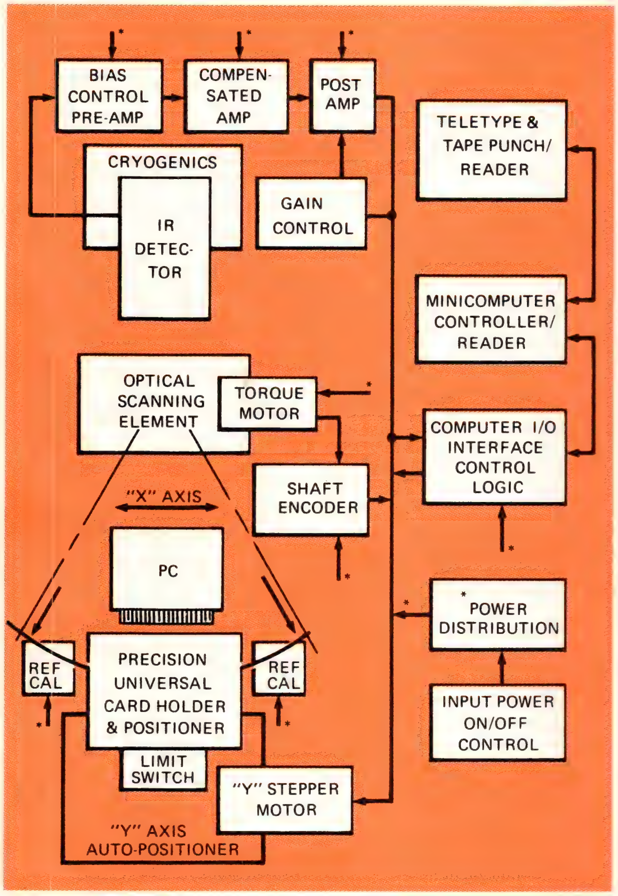


Fig. 6—INSPECT system combines the technologies of optics and electronics, producing a unique pc board tester.

detector depends on responsivity, time constant, spectral response and noise equivalent power (NEP).[3]

As has been true in other areas of electronics, the military often funds—and classifies—advance development. And IR technology is no exception. But the lack of knowledge about the latest detector should not be too big a drawback, since there is still a great amount of unclassified material to work with.

IR supplies a private line

In the communications field, the Santa Barbara Research Center has developed a hand-held gallium arsenide IR laser optical communicator. Their latest voice communicator, model 46352C, uses half of a pair of binoculars. Add to this the transmitter and receiver **(Fig. 5)** and the maximum communication range stretches for five miles. Using FM modulation of the laser beam, the peak power output of the transmitter is 20W.

This system provides completely private communication. A receiver would have to be in the line of sight for an operator to realize that a transmission was taking place. Other major advantages include full duplex operation and a system that cannot be jammed.

IR mating with fiber optics

The coupling of fiber optics with IR detectors produces results not obtainable by any other means. Fibers permit detectors to be located remote from hostile environments. Examples include microwave ovens, electromagnetic fields in an induction oven, or any other environment too severe for the detector.

The Vanzetti Infrared and Computer Systems Co. of Canton, MA, has developed several systems using this technique. Motorola now uses one to control an induction reactor in the manufacture of semiconductors. Another recently developed system measures the temperature of the blades in a turbine engine. This system is sensitive enough to determine if a single blade is getting too hot.

A crystal ball for printed circuits

Surely one of the most interesting IR systems for the electronics industry tests circuit boards. Every component on a board emits IR. When in operation, all parts will be warmer than ambient. If the board is malfunctioning, the power being dissipated changes, causing change in the emitted IR frequency and power. Therefore, a normally operating board produces a unique "infrared signature"; an abnormal board produces an abnormal signature.

Consequences of this are significant and multiple. First, testing of a circuit board with an IR scanning system tests all components, not just the specific points probed in an electrical test. Second, measurements are made without any contact to the board. This eliminates loading errors on high impedance circuits and eliminates safety and measurement problems on high-voltage circuits. Third, passive IR scanning can eliminate most early component failures that occur after a system has been shipped. These failures usually can be traced to an overstressed condition. That overstressed component may pass an electrical test, but more than likely, the problem will show up in an IR test due to its power dissipation being out of specification. Fourth, this type of test can eliminate some Q-A inspections because even a bad soldered connection will show up.

When the IR testing system is coupled to a computer, you end up with a very powerful tool. The system just described has been built by Vanzetti (**Figs. 6** and **7**). Called the INSPECT system (Infrared Noncontact System for Printed-circuit and Electronic Component Test), it comes fully programmed for both testing and troubleshooting. The only things needed for each pc card are the X and Y coordinates for the component. This can be taken care of by an

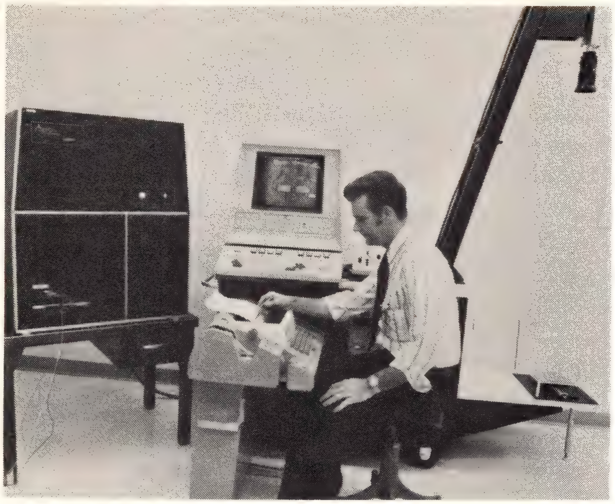


Fig. 7—Combining IR scanning and TV, this version of an INSPECT system was developed for NASA. The pc under test is in the chamber on the left. A TV camera on the boom looks at another (same type) pc board or schematic. The TV screen displays the superimposed image of the temperature over the components on the board or the schematic.

optional device (an X-Y locater) that any unskilled operator can handle.

In operation, the system produces a printout that lists all components. It tells whether the component is out of temperature limits, how far out, and whether it is above or below the specification.

From autos to amusements

Many additional applications exist. IR microscopes from Barnes Engineering Co. will do in a manual mode for IC's what the Vanzetti system does for pc boards. A system developed by the Lockheed Missles & Space Co. remotely monitors an automobile's exhaust. Electro-optical shaft encoders are replacing potentiometers in electronic games made by Atari (even the most rugged pots wear out in two months). These encoders use IR because more efficient optical couplers are available in the IR range than in the visible range.

The IR applications list is expanding rapidly as the technology becomes a working tool, moving out of the laboratory into the field. ▭

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2. *Hudson, Richard D. Jr., "Infrared Systems Engineering," John Wyle & Sons, 1969.*
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New CMOS voltage translation and buffering techniques

Optimized systems frequently mix logic families. In such cases, approaches presented here will ensure proper interfacing.

Thomas P. Redfern and **John Jorgensen**, National Semiconductor

In many applications CMOS has proved to be the ideal choice because of its unique advantages over other logic families. These advantages include extremely low power, high-noise immunity, wide power supply range, and good speed performance.

There are, however, areas where CMOS is not the logical choice. For instance, in the ROM and Shift Register area, standard p-channel MOS is clearly superior. Also, when interfacing to non-CMOS systems, the interface previously has been economically unfeasible. This was particularly true for small CMOS systems, where the cost of the interface could exceed the cost of implementing the given function.

To help tip this trade-off in favor of CMOS, four new hex buffers have been designed. Some of the unique interface advantages of the 54C/74C901, 902, 903 and 904 will be discussed.

Interfacing PMOS to CMOS

Since most PMOS outputs normally can pull more negative than ground, the conventional CMOS input diode clamp from input to ground poses problems. At the very least it increases power consumption, because even though the output is clamped at one diode drop (−0.6V), all the current that flows comes from the PMOS negative supply. For TTL-compatible PMOS this equals −12V. Since a PMOS output designed to drive one TTL load will typically sink 5 mA, the total power per TTL output is then 5 mA×12V = 60 mW.

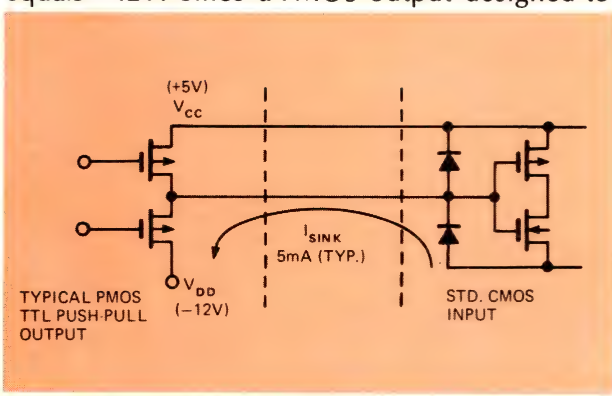


Fig. 1—CMOS input diode clamp increases power consumption when being driven by PMOS device. Currents >5 mA can cause catastrophic failure of the CMOS input.

The second PMOS/CMOS interface problem is more serious. Currents of 5 mA or greater from a CMOS input clamp diode can cause 4-layer diode action on the CMOS device. This, at best, will totally disrupt normal circuit operation. At worst, it will cause catastrophic failure.

To overcome the problem, the MM74C903 and MM74C904 have a clamp diode from inputs to V_{CC} only. This diode provides adequate static discharge protection and, at the same time, allows voltages of up to −17V on any input. Since there is essentially no current without the diode, both the high power-dissipation and latch-up problems are eliminated.

To demonstrate the above characteristics, **Figs. 1, 2** and **3** show typical TTL-compatible PMOS circuits. The first drives standard CMOS with two clamp diodes; the second drives an MM74C903/MM74C904; while the third shows a PMOS-to-CMOS system interface.

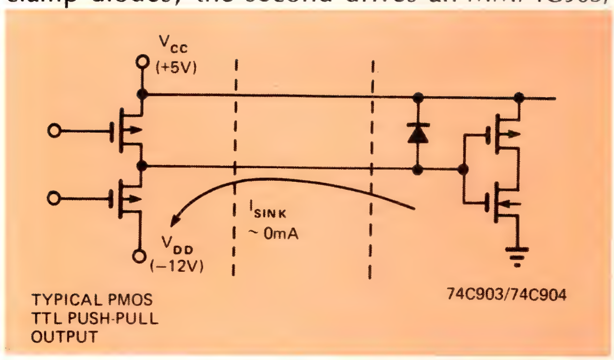


Fig. 2—In the 74C903/74C904, clamp diode is from inputs to $+V_{CC}$ only. This allows voltages of up to −17V on any input, while providing adequate static discharge protection. Power dissipation and latch-up problems are eliminated.

CMOS-to-CMOS or TTL interface

When a CMOS system operating at V_{CC} = 10V provides signals to a CMOS system whose V_{CC} = 5V, a problem similar to that found in a PMOS-to-CMOS interface occurs. That is, current can

flow through the upper input diode of the device operating at the lower V_{CC}. This current could be in excess of 10 mA on a typical 74C device **(Fig. 4)**. Again, this causes increased power dissipation as well as possible 4-layer diode action.

Using the MM74C901 or MM74C902 eliminates the problem simply because these parts are designed with the upper diode removed **(Fig. 5)**. Without this diode, the current being sourced goes from about 10 mA to the very low leakage current of the reverse-biased input diode.

The MM74901 and MM74902 can drive two standard TTL loads with only normal input levels. The MM74901's output drive increases as V_{IN} increases; e.g., it can drive four TTL loads when

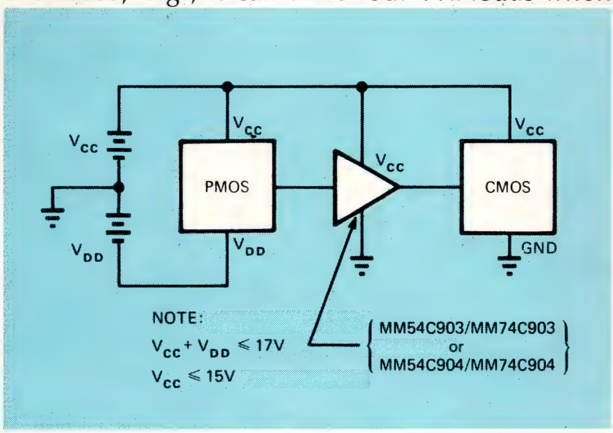


Fig. 3—Safe yet effective PMOS-to-CMOS system interface is summarized in this block diagram.

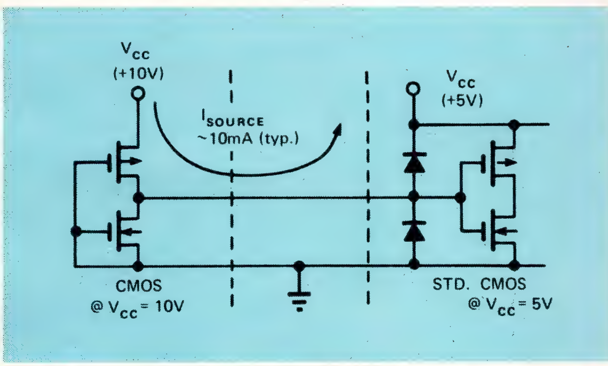


Fig. 4—Source current exceeding 10 mA could flow through a CMOS-to-CMOS interface when the input device is operating at a lower voltage. Again, this can cause disastrous results.

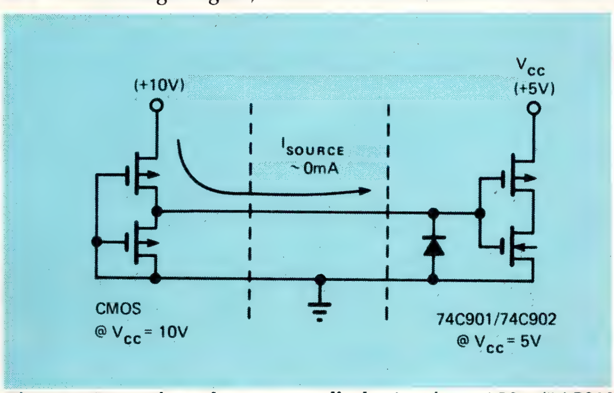


Fig. 5—Removing the upper diode in the 74C901/74C902 reduces the source current to the level of the leakage current of a reverse-biased diode.

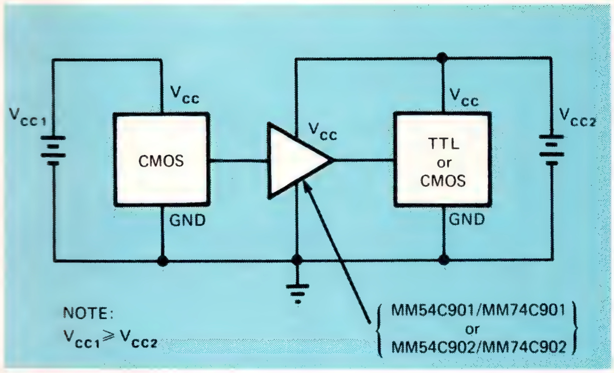


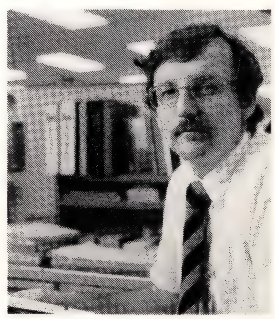
Fig. 6—As long as $V_{CC1} \geq V_{CC2}$ and grounds are common, 74C901/74C902 can use any combination of supplies between 3 and 15V.

V_{IN} = 10V. This is not true of the MM74902, however. Its output drive remains constant with increased input voltage because the gate of its output n-channel device always is driven by an internal inverter whose output equals the device's V_{CC}.

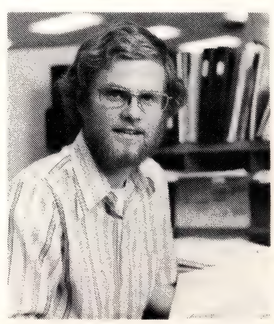
While **Fig. 5** showed V_{CC} = 10V on one system and V_{CC} = 5V on the second, the MM74C901 and MM74C902 are capable of using any combination of supplies $3V<V_{CC}<15V$, as long as $V_{CC1} \geq V_{CC2}$ and the grounds are common. **Fig. 6** diagrams this configuration.

The inputs on these devices are given adequate protection with the single diode. However, as with all MOS devices, normal care in handling should be observed. □

Authors' biographies



Thomas P. Redfern is MOS applications manager at National Semiconductor Corp., Santa Clara, CA. A Stanford man, he received his BSEE in '63 and his MSEE in '64. Tom lives in San Jose and enjoys gardening and model railroading.



John Jorgensen is CMOS design manager at National Semiconductor. He received his BSEE from Purdue Univ., where he was honored with memberships to Tau Beta Pi and Eta Kappa Nu. John has been granted a patent and lives in Santa Clara.

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Test your PLL IQ

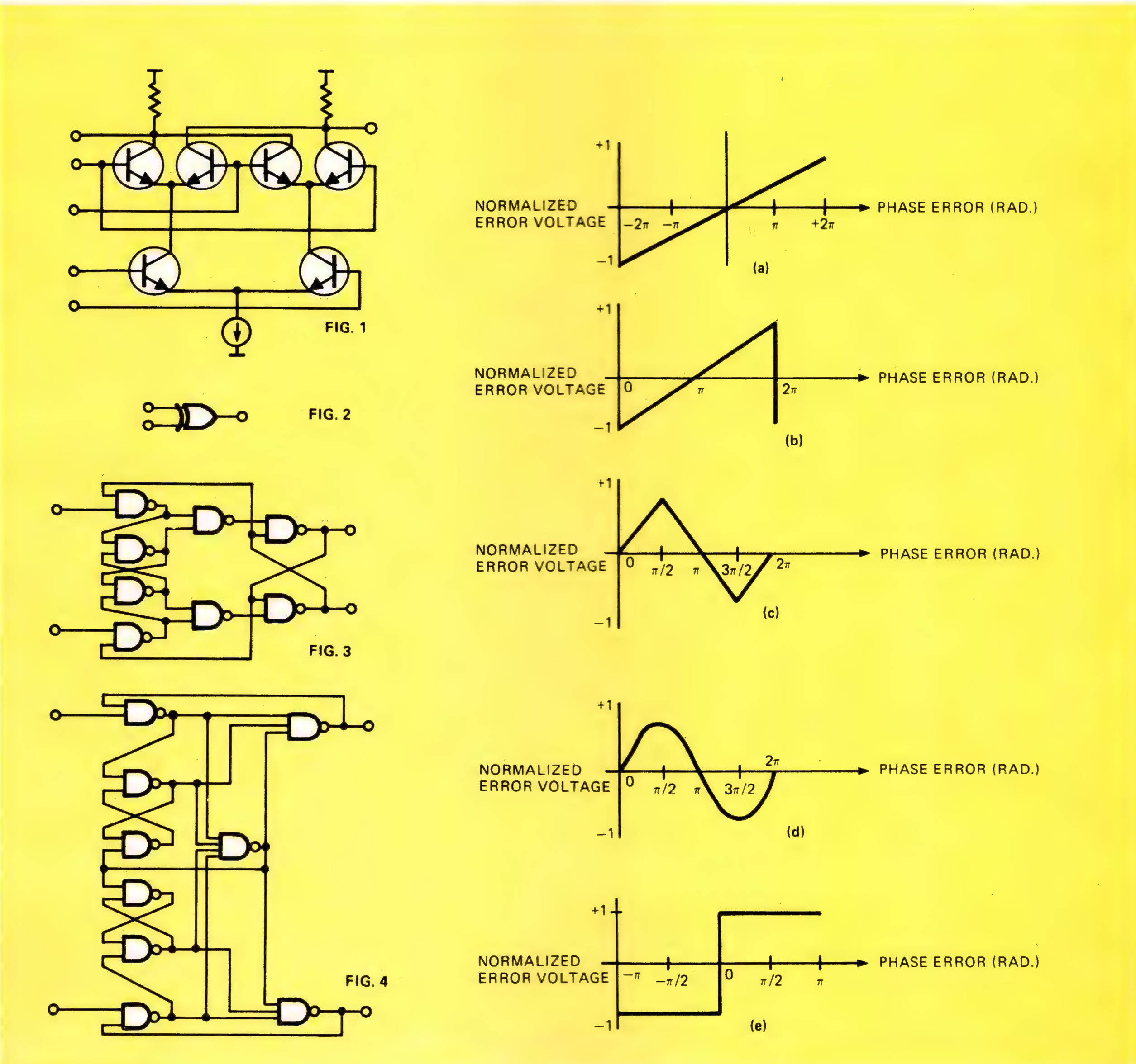
Do you feel you know enough to have complete confidence in your PLL designs? This short quiz should help you find out.

L. J. Reed and **Ron J. Treadway,** Motorola Semiconductor

Almost daily, we receive inquiries from designers seeking assistance with their phase-locked loop applications. The questions which make up this quiz are representative of those asked most often by these designers.

The quiz is made up of 14 multiple-choice questions. They are oriented toward the use of integrated circuits in frequency synthesizer applications. Most questions require little, if any, calculations, and can be answered by reasoning. We must, however, inject a word of caution. Some questions have more than one correct answer. Read all of the choices before answering and proceeding to the next question.

1. Match the phase detector circuits shown with the appropriate transfer function.



2. Which of the following characteristics make the exclusive-OR gate undesirable as a phase detector in a frequency synthesizer?

a. risetime sensitive
b. prone to false locking
c. specific input levels required for proper operation
d. high feedthrough at twice the reference frequency
e. insufficient gain
f. susceptible to AM components
g. 50% duty cycle input required for proper operation

3. Which of the following characteristics make the phase detector shown in **Fig. 4** desirable for use in frequency synthesizers?

a. error voltage duty cycle approaches zero in a locked loop
b. phase and frequency sensitive (cannot false lock)
c. unlimited capture range
d. duty cycle of input waveform is unimportant
e. all of the above

4. From the output error signal shown in **Fig. 5**, calculate the phase detector gain constant K_ϕ.

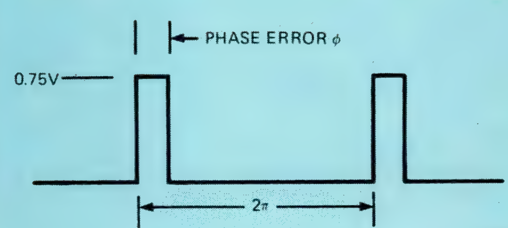


Fig. 5

a. 0.375 volts/radian
b. 0.12 volts/radian
c. 0.24 volts/radian
d. none of the above

5. Compute the gain constant, K_ϕ, for the phase detector transfer function shown in **Fig. 6**.

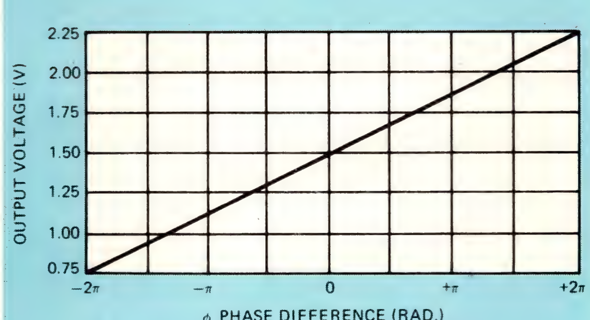


Fig. 6

a. 0.36 volts/radian
b. 0.12 volts/radian
c. 0.59 volts/radian
d. 2.25 volts/radian

6. The voltage controlled oscillator selected for a synthesizer application has the characteristic shown in **Fig. 7**. Calculate the VCO conversion gain over the linear portion of the curve.

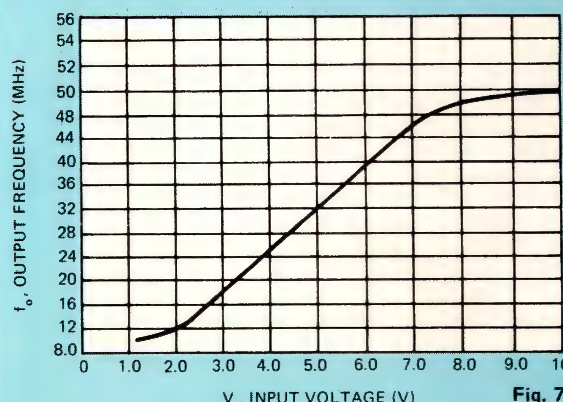


Fig. 7

a. 40.2×10^6 radian/sec-volt
b. 41.1×10^6 radian/sec-volt
c. 4:1
d. 30.2×10^6 radian/sec-volt

7. High frequencies must be scaled down to be compatible with TTL programmable counters. One economical method uses a "D"-type flip-flop as a digital harmonic mixer. A typical configuration is shown in **Fig. 8**. For this configuration, which of the following statements are true?

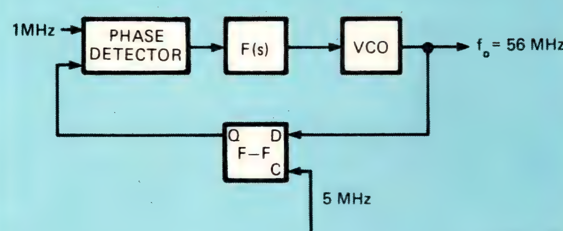


Fig. 8

a. VCO tuning must be restricted to the range of 54 to 59 MHz
b. the gain constant of the mixer is 1/11, since we are mixing with the 11th harmonic of the 5 MHz source
c. output frequency of the "D" flip-flop is 1 MHz
d. a and c
e. all of the above

8. A second technique for scaling down high frequencies into a range compatible with programmable counters is called fixed prescaling. This technique involves insertion of high frequency fixed dividers preceeding the counters. What can be stated about fixed prescaling?

a. the required reference frequency is raised
b. the required reference frequency is lowered
c. the required channel spacing cannot be achieved
d. the loop gain is lowered
e. none of the above

9. **Fig. 9** is a block diagram of a technique that eliminates the disadvantages of fixed prescaling. Which of the following characteristics apply to this 2-modulus technique?

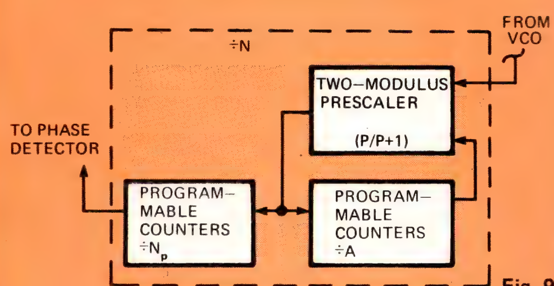


Fig. 9

a. total division is $N = N_p P + A$
b. N_p must be greater than A for proper operation
c. the higher modulus (P + 1) increments both counters; the lower modulus (P) increments only the N_p counter
d. all of the above
e. none of the above

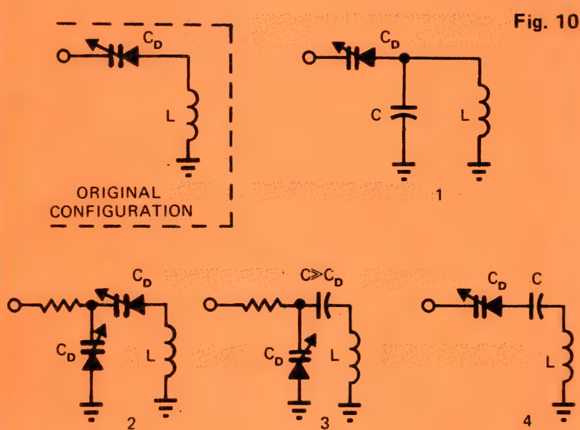


Fig. 10

10. A possible tank circuit configuration for a VCO is shown in **Fig. 10**, along with four circuit modifications. Match the following statements to the appropriate circuit.

a. decreases operating frequency and conversion gain
b. will not tune
c. same as original
d. increases operating frequency and conversion gain
e. center frequency lowered

11. The specifications for a PLL synthesizer are as follows:

output frequency, f_o, = 2 − 3 MHz
channel spacing = 50 kHz
locktime between channels (to 5%) = 2 msec max.
overshoot less than 40%

Assume the system is a type 2 loop with the step response shown in **Fig. 11**. Select the minimum ζ that will meet the specifications, and calculate ω_n and the minimum tuning range for the VCO.

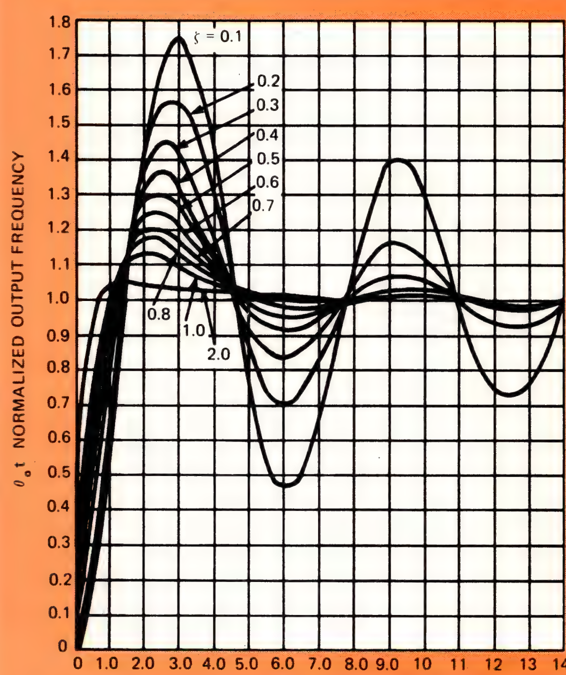


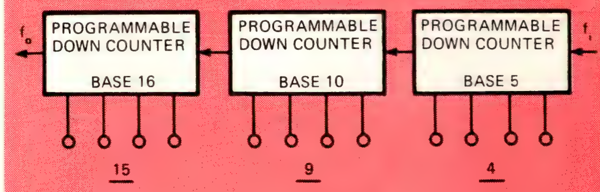
Fig. 11

a. ζ min. = 0.4, ω_n = 2250 radians/sec, min., VCO tuning range = 3.5:1
b. ζ min. = 0.5, ω_n = 3000 radians/sec, min., VCO tuning range = 3.5:1
c. ζ min. = 0.4, ω_n = 3500 radians/sec, min., VCO tuning range = 2.1:1
d. ζ min. = 0.4, ω_n = 3500 radians/sec, min., VCO tuning range = 3.5:1
e. none of the above

12. Although a directly programmable ÷ N section is desirable in many applications, it is not

always an easy requirement to meet. One technique for obtaining the desired programming is the use of counters of different bases in the counter section. For the number programmed in the block diagram of **Fig. 12**, what is the total value of division?

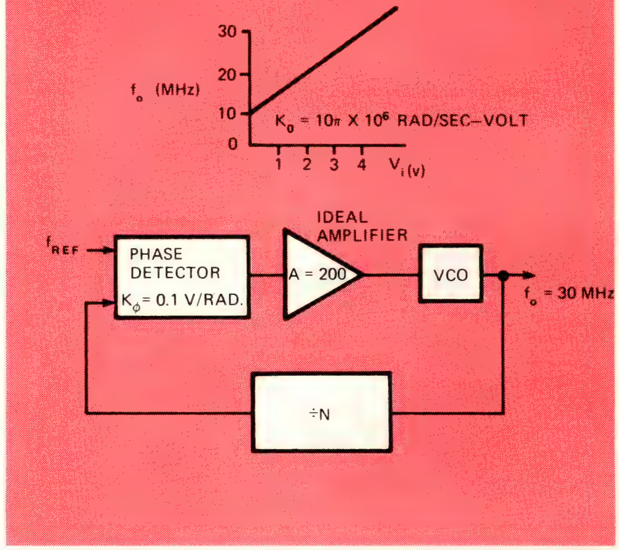
Fig. 12



a. 797
b. 1594
c. 799
d. 540
e. none of the above

13. A theoretical PLL is shown in **Fig. 13**. For the characteristics shown, what is the phase error between the phase detector inputs when the loop is locked?

Fig. 13



a. 0
b. 0.2 radians
c. 0.1 radians
d. 0.5 radians

14. What is the loop gain, K_v, for the system shown in **Fig. 13**?

a. $K_v = K_\phi K_0 A = 200\,\pi \times 10^6$/sec
b. $K_v = K_\phi K_0 = \pi \times 10^6$/sec
c. $K_v = AK_0 = 2000\,\pi \times 10^6$/sec
d. insufficient information

Answers to this quiz appear elsewhere in this issue. □

EDN µP DESIGN SERIES

Newest µP's split into two divergent paths

Microprocessors are becoming increasingly sophisticated, blazing new trails in computer architecture.

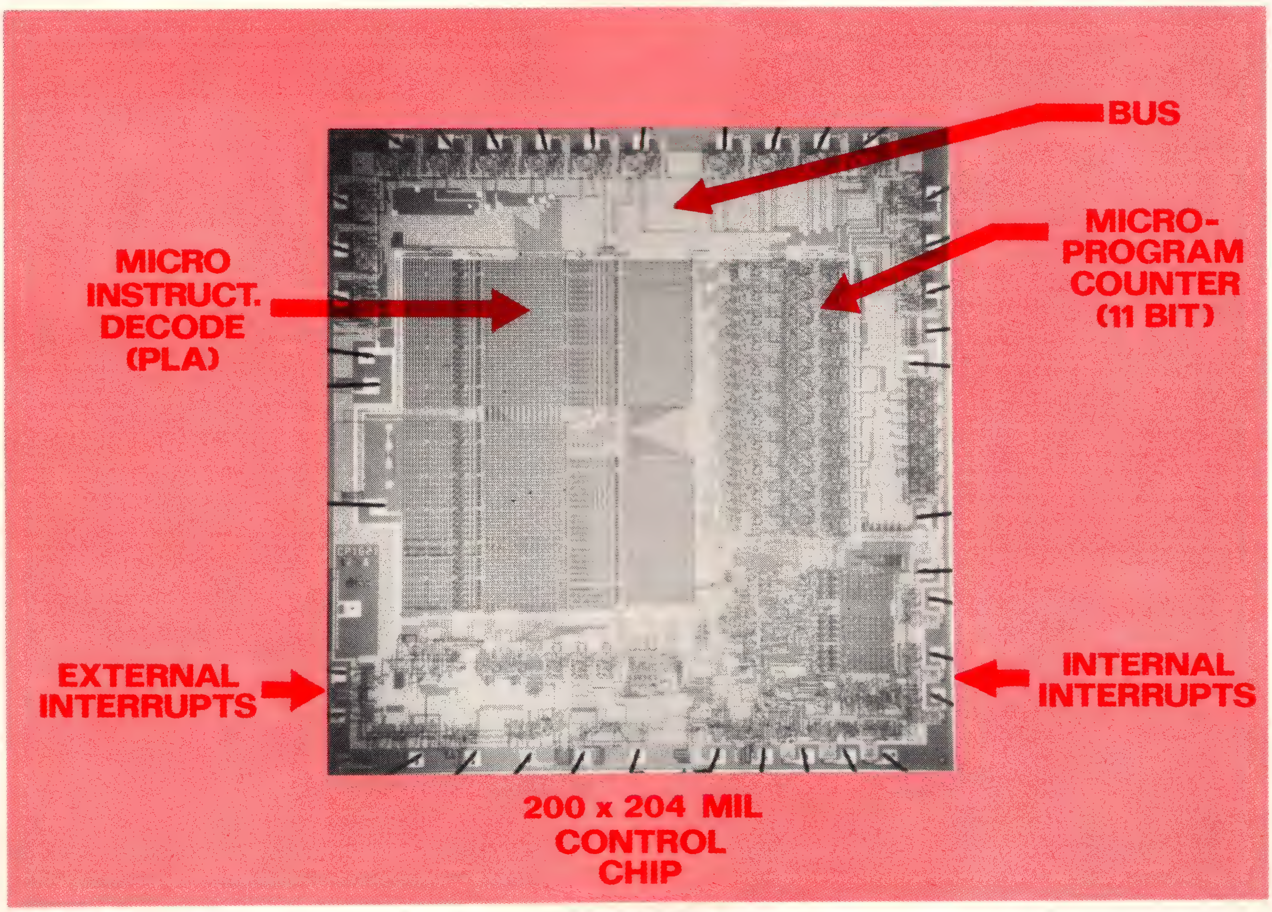
Robert H. Cushman, Special Features Editor

The MOS microprocessors now becoming available are of two distinct types. Three 16-bit machines—National's PACE, General Instrument's CP-1600 and Western Digital's MPS-1600—copy well-known minicomputers so closely that any remaining arguments about whether a mini can be reduced to a few chips of LSI become academic.

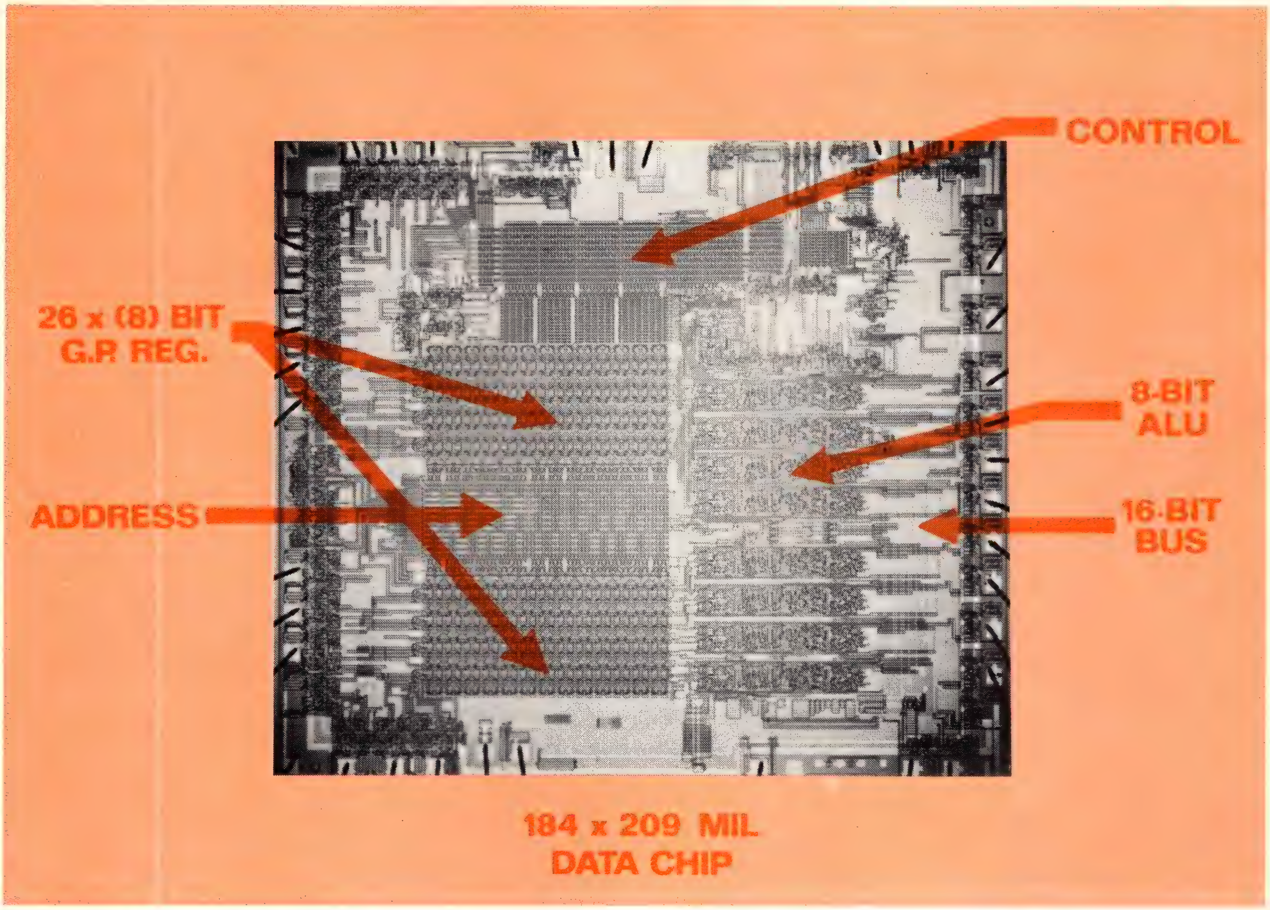
On the other hand, three 8-bit machines—Fairchild's F-8, Mostek's 5065 and Rockwell's PPS-8—pioneer such novel architectural twists that they really have no antecedents in the minicomputer world.

Copying the mini's

National Semiconductor's PACE is a 1-chip-CPU copy of their older multi-slice IMP-16, which in turn was a copy of the Data General NOVA-1200



Wide 16-bit buses eat up chip real estate on µP's like Western Digital's MPS-1600. But the situation isn't quite as bad as it looks, because the area where the buses run doesn't carry active devices. Thus silicon crystal defects in these regions don't hurt yield. This is one of the MPS-1600's chips.



When used for a PDP-11 emulation, Western Digital's MPS-1600 runs only 10% slower than the bipolar machine. One problem you face with such a high-speed system is that you can't get away with finer geometry polysilicon buses. Instead you must use low-impedance metal lines, according to W.D.'s William Pohlman. Shown is another MPS-1600 chip.

minicomputer. General Instrument's CP-1600, a 1-chip CPU, copies the DEC PDP-11 mini. And Western Digital's MPS-1600 is a several-chip-CPU microprogrammable building block that Digital Equipment Corp. uses to replicate its PDP-11/05.

The degree to which these μP's implement full-grown mini's within the confines of a few specks of silicon should convince any remaining doubter that the μP era is here. Even if you don't care about the promise of reduced price, how can you ignore the jump in reliability?

Uniquely different approaches

Fairchild Semiconductor's F-8 takes the PC (program counter) out of its usual place in the CPU and RALU (register and arithmetic and logic unit) chip and duplicates the PC in each of the ROM and memory-interface chips.

Mostek's 5065 triplicates the PC and the accumulator, forming what amounts to three separate CPU's sharing one ALU, all inside one chip.

Rockwell's PPS-8's uniqueness lies not in any one obvious CPU architectural feature, but in the many little sophisticated systems-level innovations throughout all the family's LSI chips.

These three μP's foretell of the many new directions that LSI technology will engender in computer system architecture.

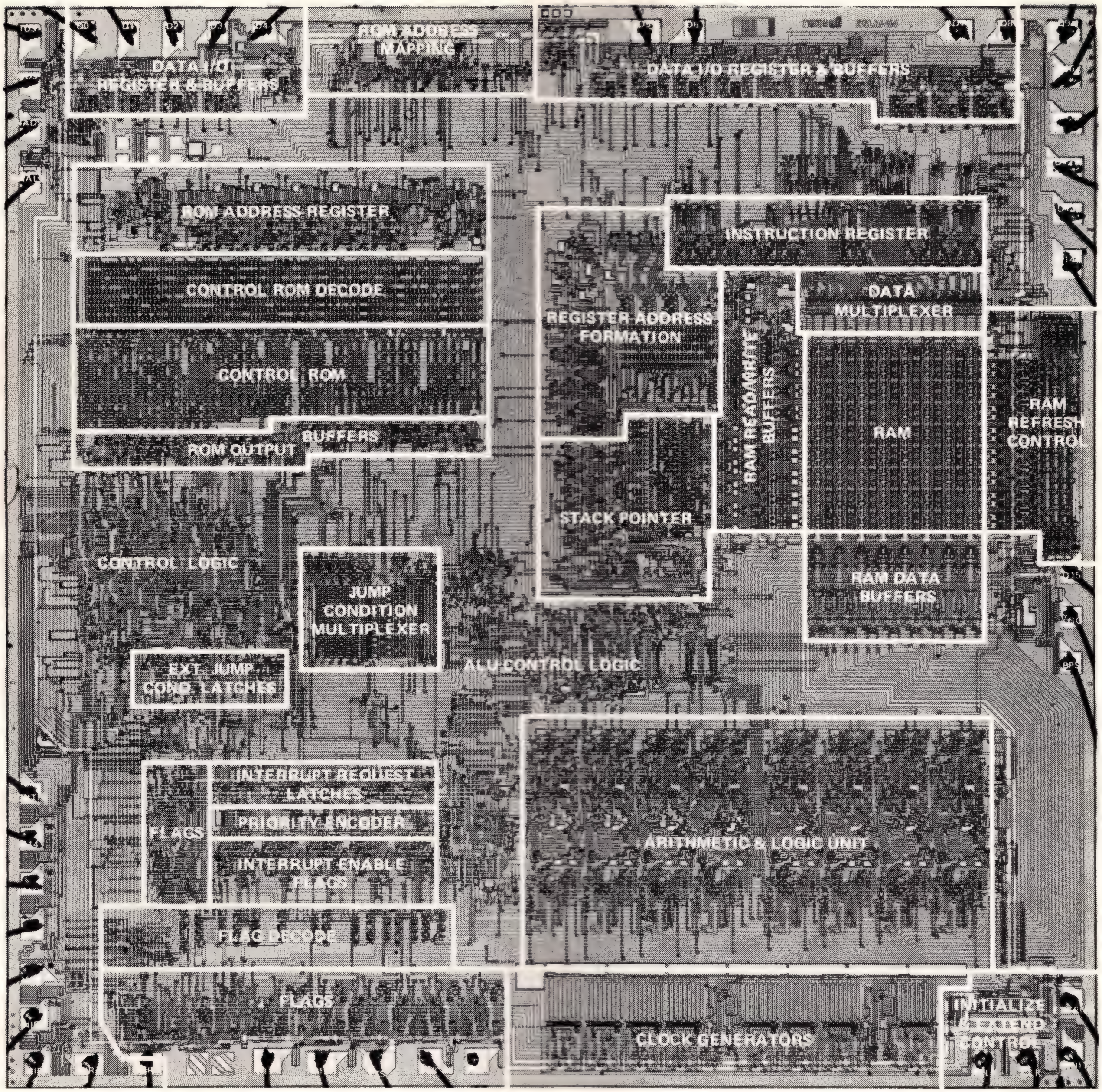
PACE is revealed

Of these six new μP's, the National PACE deserves the most attention because very little information has previously appeared about it. (See EDN's μP directory in the Nov. 20th issue for thumbnail descriptions of hardware and software of the other five machines.)

PACE stands for "programmable arithmetic and control element." In the device itself, National has consolidated 90% of the capability of its older multi-slice IMP-16 μP on a single chip. PACE's fixed instruction set includes 43 basic IMP-16 commands. In addition, PACE has commands that enable it to handle data on a full 16-bit-wide basis.

Fabricated in the same older silicon-gate pMOS technology used for the IMP-16 slices, PACE nevertheless stands out unique among μP's as the first to sport a full 16-bit wide ALU in a single chip. Both the G.I. CP-1600 and the W.D. MPS-1600 actually have only 8-bit wide ALU's—though they use the newer NMOS technology.

Because it's a pMOS device, PACE runs rather



National Semiconductor's PACE partially offsets the area consumed with the wide buses by not attempting to put off-chip driving capability at the outputs. Thus, unlike most other μP's, there are no large driver transistors around the edge of this 1-chip, 16-bit, pMOS CPU. National uses special external buffers to do the bus driving.

slow, taking 10 μsec to execute typical instructions. But National says the wide 16-bit instruction word and the four CPU accumulators with indexable addressing allow PACE to match the computing throughput of 8-bit μP's that execute instructions in 5 μsec.

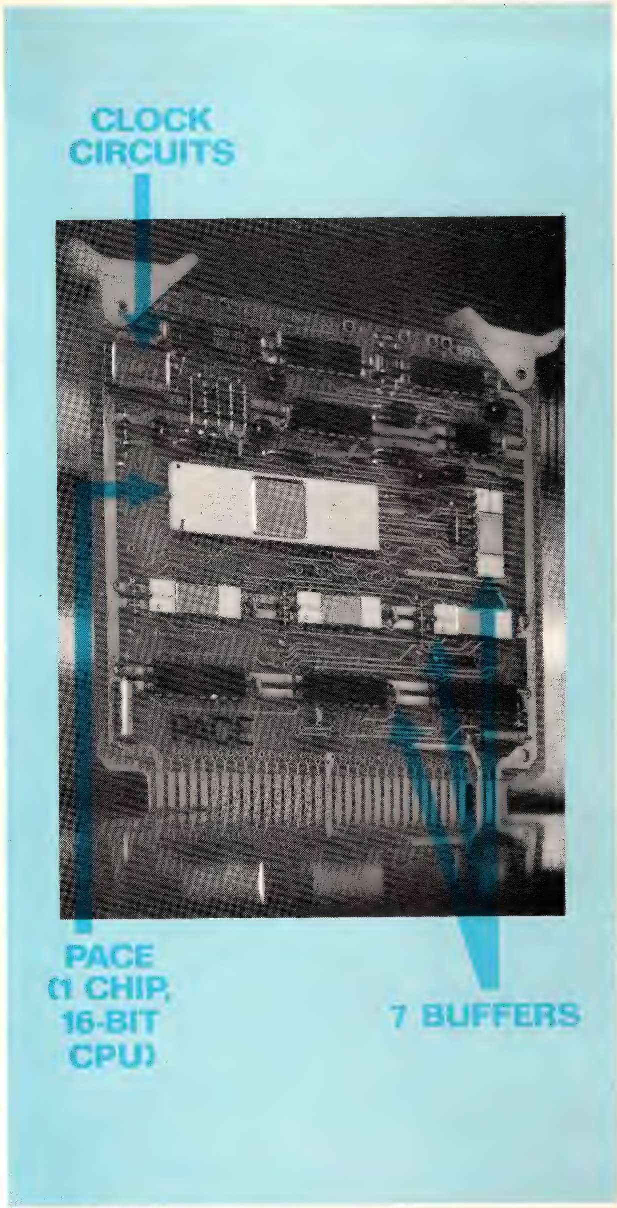
(Incidentally, Rockwell's PPS-8, which uses an even more ancient metal gate pMOS, has evidenced an amazing ability to compete speedwise with the fast Motorola 6800 and Intel 8080 NMOS μP's.)

Outboarding the buffers

To run down other points of comparison, consider the following:

1. PACE has a 10-deep push-down stack, while IMP-16's stack is 16-deep.
2. PACE uses common addresses for memory and I/O. The IMP-16 uses separate I/O instructions.
3. PACE carries features like interrupt on its single chip, while IMP-16 has them outboarded in TTL.

National says it has been able to put PACE on a 235-mil square die. They achieved this despite the need to run 16-bit-wide buses about the chip. (Photos show how much real-estate these wide buses take up.) Key to this accomplishment is that



This single 4.5 in.² card from National Semiconductor contains a complete data processing controller. By employing PACE's powerful instruction set and by taking advantage of powerful interrupt circuitry, systems designers can perform in software many functions that previously had to be done with extra hardware.

no attempt has been made to obtain off-chip drivers. Instead, National uses outboarded buffers, six to a package. The current-sense inputs of these buffers transform the feeble pMOS outputs into healthy TTL outputs.

National has priced PACE at $141 in hundreds, but the story certainly won't end there. Just think of what NSC could do to μP pricing if it decided to be as aggressive in the μP marketplace as it has been in the pocket calculator market. In the latter, National now sells calculators to the general public at $16 apiece—and claims to be making a healthy profit! □

Electronic Component Leadtime Index

December 1974

	Leadtime in weeks: Min.	Max.	Trend
CAPACITORS			
Ceramic	5	13	▼
Electrolytic			
aluminum	8	18	▼
tantalum	7	16	▼
Film	6	11	=
Mica	7	14	▼
Paper	8	13	▲
Trimming	5	9	=
CONNECTORS			
Coaxial	5	10	▼
Multipin circular			
high-density	8	16	▲
standard	6	11	=
Printed-circuit	5	10	▼
Rack & panel	5	9	▼
INTEGRATED CIRCUITS			
DTL	6	13	▼
ECL	2	10	▼
TTL	5	12	▲
MOS	5	13	▲
CMOS	5	13	▼
Op amps (monolithic)	7	12	▼
Voltage regulators	3	10	▼
PACKAGED CIRCUITS			
Digital logic	5	8	▲
Op amps (hybrid & discrete)	3	11	▲
PRINTED CIRCUITS			
Multilayer	9	14	▲
Two-sided	4	9	▲
RELAYS			
Crystal-can	10	15	▲
Reed	7	11	▲
General-purpose	5	8	▲
Stepping	8	12	▲
Telephone	8	11	▲
Solid-state	7	10	=

	Leadtime in weeks: Min.	Max.	Trend
RESISTORS, FIXED			
Composition	3	8	▼
Dep.-carbon & carbon-film	4	10	▼
Metal-film	6	16	▼
Wirewound	5	11	▼
RESISTORS, VARIABLE			
Nonwirewound			
nonprecision	2	7	▼
precision	5	13	▲
Trimmers	4	10	▼
Wirewound			
nonprecision	3	9	▼
precision	6	13	▲
trimmers	4	9	▼
SEMICONDUCTORS			
FET's	3	8	▼
Power rectifiers	4	10	▲
Power transistors	3	11	▼
SCR's & triacs	4	11	▲
Silicon switching transistors	5	15	▲
Switching diodes	4	11	▼
Zeners	4	13	=
SWITCHES			
Lighted pushbutton	7	11	▼
Pushbutton	5	9	▲
Rotary	6	11	=
Snap-action	5	10	▼
FANS & BLOWERS	10	22	=
FRACTIONAL H.P. MOTORS	9	30	▼
WIRE & CABLE	6	15	▼
PANEL METERS	10	15	▲
LIGHT-EMITTING DIODES	5	10	▲
READOUTS & DISPLAYS	5	11	▲

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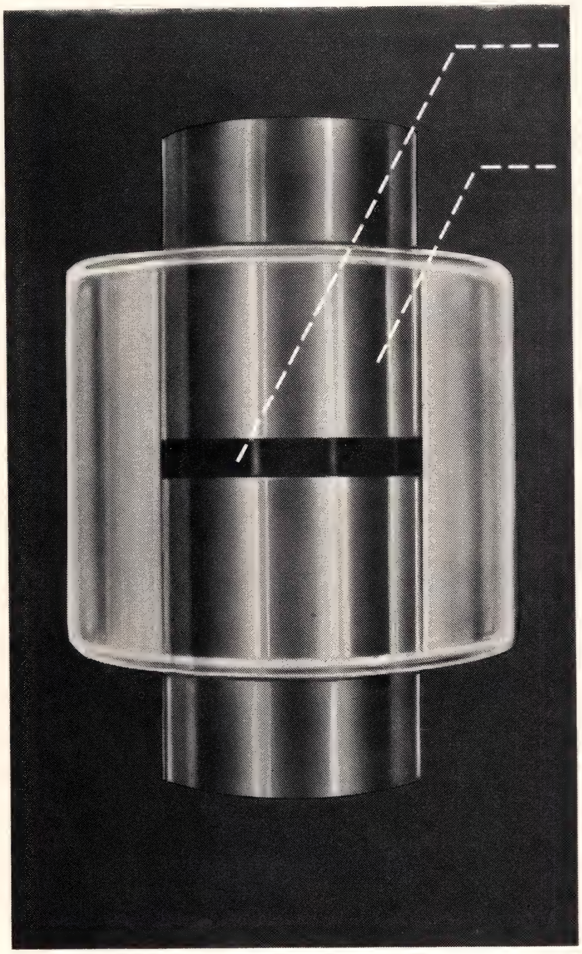

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Trying something new? These safe-guards can help insure success

Common sense often beats following rules when you need to evaluate a new idea. Let these 18 practical tests help you decide what to do.

Thelma L. Fair

New steps in any working procedure present a hazard, yet without them there can be no advancement. Here are several check points to help you remove much of the risk from the steps you take in the future.

• Has the step you are contemplating been tried before in this area of application? An idea that's new to you could well have been tried before—but in the wrong way, at the wrong time or with the wrong approach—so don't set it aside solely because it isn't new.

• Does your "new" idea run counter to solidly entrenched industry procedures or practices? If so, be sure it has enough merit to warrant the expense and effort required to implement it. Also, retain as many good features of the old ways as possible.

• Can you be definite on the costs involved? They have a way of becoming greater than first projected because of the surfacing of new approaches and unexpected requirements. You can never check costs too frequently.

• Are all participants in the idea's implementation well prepared to make it work? You'll need team effort for success, so plan to sell them on the idea well before it reaches the assignment stage.

• Is your timing advantageous? Be certain the plan's introduction is helped, instead of hindered, by the date you have chosen for its introduction. It might have a better chance for survival if launched at another time.

• Make sure that all details have been worked out completely. Neglect of "small" things frequently leads to the downfall of a new idea. It is all too easy to concentrate on big problems while small ones drag progress to a halt.

• Set up the program to allow time for the new product or service to become profitable. Few ideas are effective in a short period of time.

• Will implementing your idea result in the revamping of procedures currently in use? If so, solutions should be worked out in advance—not afterward.

• Remain flexible. Modifications are inevitable when any idea is put into action. Don't let them throw you. Encourage your personnel to suggest solutions to problems that come up.

• As the idea's advocate, you are well aware of its virtues, but others may not recognize them immediately. Include a brief summation of them as part of your overall effort. It will speed acceptance.

• Build as many back-up steps as possible into your plan before launching the new idea. These can counter many of the temporary roadblocks that arise.

• Guard against elaborate plans or programs. Simple, direct working ideas have a greater chance for success.

• Be realistic in setting goals for your new idea. It's a truism that achieving modest goals gives much more satisfaction than failing to reach ambitious ones.

• Does the overall plan for your new idea contain an orderly procedure for its abandonment if things should go wrong? Such a contingency plan has merit as a safeguard, even though it probably won't be needed.

• Reduce uncertainty to the bare minimum. Guesswork is a burden no idea should have to carry.

• Have you fully explored all the applications of your new idea? It may have side uses that, if properly exploited, will materially enhance its ultimate value.

• Be sure that you have all necessary equipment, supplies and materials on hand for the implementation of your idea.

• Is it possible to test your new idea in a small way first? This is an excellent approach for working out the bugs, and often helps in uncovering new or better applications.

If you take the time to go through the suggestions again, applying them to some idea that fell short of its goal, their value will be apparent. More than likely you'll find out why things went wrong—and possibly will see how to give that idea a successful second try. ▭

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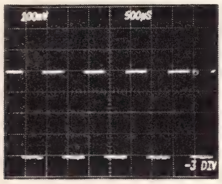

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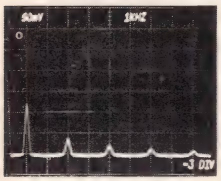

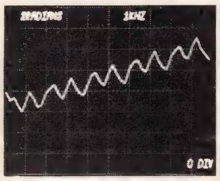

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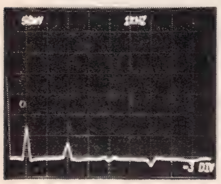

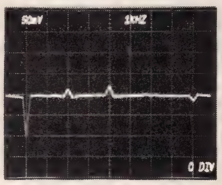

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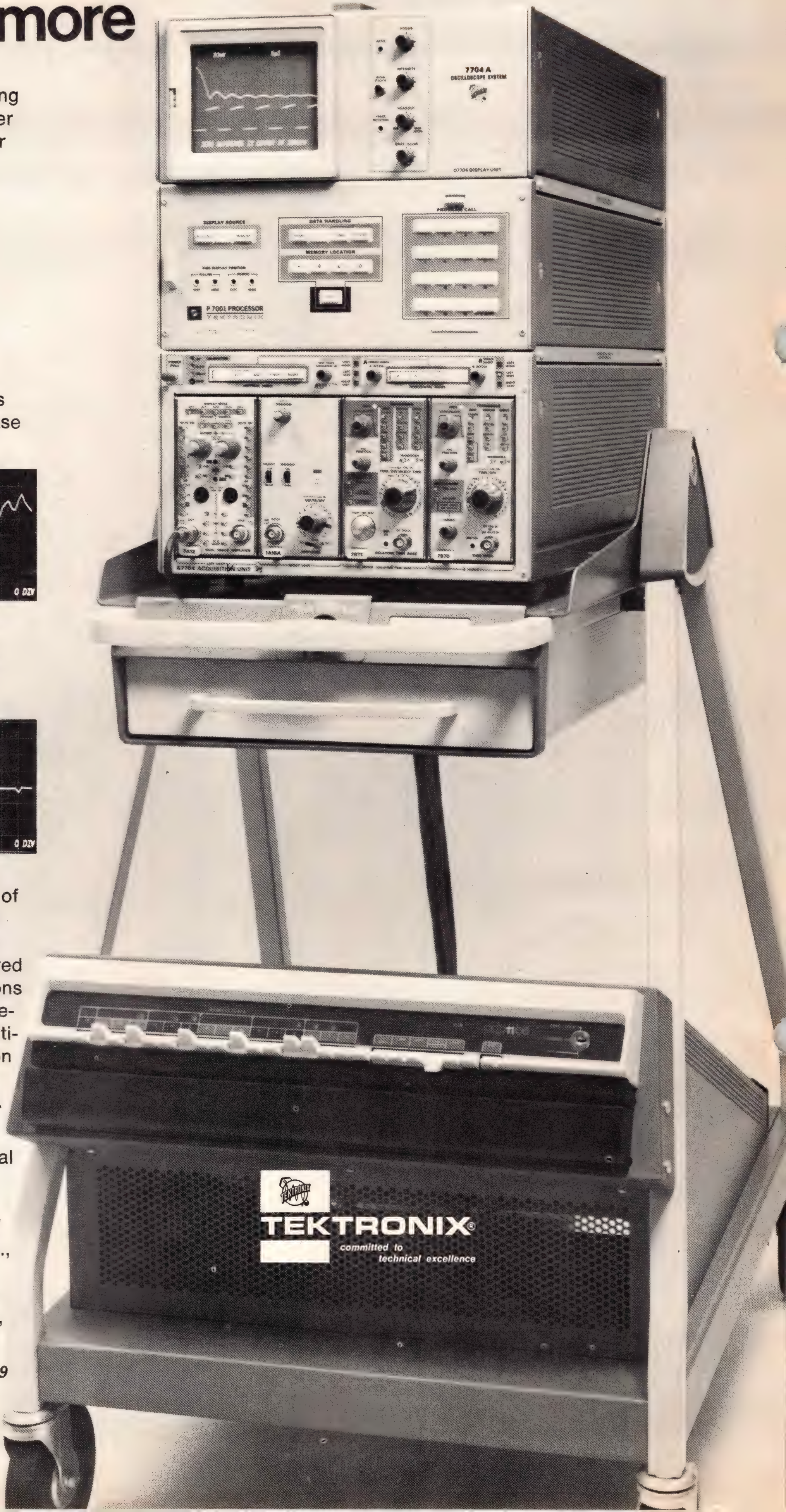

User microprogram development for an LSI processor

Adjusting system architecture to the specific application simplifies programming and improves throughput. Here's how it's done.

Alan J. Weissberger, National Semiconductor Corp.

The customizing craze has hit the microprocessor field. No, you won't see racing stripes, or slotted-chrome wheels, or even dual exhausts. What you will see is more efficient microprocessor systems. Systems where it's possible to augment the existing machine instruction set, modify the interrupt servicing or I/O handling, or have the microcomputer directly execute a high-level language.

Key to these improvements is user microprogramming. The additional level of flexibility and expandability provided by microprogrammable microprocessors will be explored in this article, along with potential applications of the microprogram technique. Important characteristics and configurations of a user microprogram development system will also be described.

FREQUENTLY USED ACRONYMS

ACR = Address Control ROM
CPU = Central Processing Unit
CROM = Control and Read-Only Memory
DDU = National Semiconductor's Display and Debug Unit
FACE = Field Alterable Control Element
IMP = NSC's Integrated Micro Processor family
MC = Master CROM
MCL = NSC's Microprogram Control Logic Unit
pROM = Programmable ROM
RALU = Register Arithmetic Logic Unit
ROM = Read-Only Memory
SC = Secondary CROM
WCS = NSC's Writable-Control-Store element
XACR = Externally wire-wrapped ACR

Stack 'em up

The building-block concept is extremely useful when applied to microprocessors. It allows machines of various word lengths to be built by simply stacking similar devices in parallel.

A specific example is National Semiconductor's Integrated Micro Processor (IMP) family. CPU's with word lengths of four to 32 bits can be implemented with one to eight 4-bit Register Arithmetic Logic Units (RALU's). Control is provided through microprogrammable control elements that may be combined in parallel. The controllers may be either of the following two units: a CROM (Control and Read-Only Memory) with standard op codes and instruction sets or variations of customer-masked CROM's implementing user specified op codes and/or microprograms. Alternately, control may be provided by a more flexible unit, the Field-Alterable Control Element (FACE). It can address up to 512 23-bit words of external microcode and may be optionally hardwired for custom op-code definitions.

Since the microprogram is stored externally for FACE applications, system flexibility is greatly enhanced in a variable system development environment. Changes may be made easily as the microcode develops, without resorting to new custom masks.

Eliminating excess overhead

Special instructions such as mathematical functions, data handling and formatting, text editing, error code detection and correction can be implemented in microcode and made transparent to user software. This provides a speed improvement and main memory savings because, in general, micro-instructions are more efficient than macro-instructions.

For instance, in the case of National Semiconductor's 16-bit multiply and divide instructions, microprogramming increased effective execution speed by a factor of 6:1 while storage requirements were reduced by 13:1. Frequently called subroutines may be similarly implemented in microcode, thereby eliminating multiple instruction fetches and the overhead of getting to and returning from the subroutine.

```
000     000000    *****                                                              *****
000     000000    *****                                                              *****
000     000000    *****        MICRODIAGNOSTIC    P00007B    03/02/73     IMP-16
000     000000    ***
000     000000    ***          FUNCTIONAL CHECK OF TTL IMP SYSTEM
000     000000    ***          FLAG 8 IS USED AS A FAILURE INDICATOR AND STROBE FLAG
000     000000    ***          AND SHOULD BE CONNECTED TO JUMP COND 14 FOR CHECKOUT.
000     000000    ***          IF JC15=0 TEST WILL REPEAT CONTINUOUSLY
000     000000    ***
000     000000    *
000     000000    *            FAIL SUBROUTINE—RET ADDR SHOULD HAVE A BR ON FAILC TO START
000     000000    *                               FAIL LOOP
150     000000                 ORG       X'150
150     000210    FAIL         RFLG, FAILFF                 0           RESET FAIL STROBE
151     0001E0                 SFLG, HALTFF                 0           TURN ON HALT FLAG
152     2AA904                 B, START $+3                             ERROR STOP
153     000220                 SFLG, FAILFF                 0           SET FAIL IF LOOPING
154     600000                 RET                          0           LOOP THROUGH TEST
155     2AA904                 B, START $                               IF START WAS PUSHED
156     0001D0                 RFLG, HALTFF                 0
157     600000                 RET                          0           RELEASED, GO TO NEXT
158     000000    *                                                     INSTRUCTION
076     000000    *
076     000000    *            CHECK FLAGS AND I/O-EXCEPT PERIPH I/O, CPINP, INTEN
076     000000    *            SEL AND SVRST CHECKED IN T11
076     000000    *
076     001F40    T13          ADD, , , R7                  CIN         R7 = 1
077     00E1B0                 PFLG, LDARFF, R7             0           1 TO AR
078     00FB80                 ADD, R7, , R6                CMPA        R6=11––10
079     000070                 PFLG, WRFF, R6               0           WRITE R6 TO LOC 1
079     00F434                 PFLG, PDFF, R7, ,R5          DATAIN      READ LOC 1 TO R5
07B     07B340                 ADD, R5, R7, R4              CIN         R4=0
07C     23F044                 8,REQ0  $+2
07D     6A8404                 BSR      FAIL
07E     23B384                 B,FAILC     T13
07F     216404                 B    T14
```

Fig. 1—Portion of microdiagnostic routine used to debug National Semiconductor's IMP micro-instruction set shows how a specific function is tested by each instruction. Because diagnosis occurs at the primitive function (micro) level, you get higher resolution fault detection than possible with macrodiagnostics. This means failures can be traced faster.

Microprocessor microcoding permits the detection, classification and service of interrupts to be optimized to meet varying response time requirements of external devices. Special I/O formatting, manipulation of variable length fields, new I/O commands (if new devices are added) and special error recovery procedures (to bypass failed parts) are all candidates for micro-level implementation. Higher level language programs can be executed directly, either by a set of compile-and-run microroutines sharing control memory or by a micro interpreter. This greatly simplifies the job of the application programmer, while improving program turnaround time and efficiency.

Control algorithms and, in some cases, entire application programs can be microcoded to provide speed improvements and reduced program storage. Instruction fetch cycles from main memory are eliminated and control is at a more detailed level. Examples include digital filtering, FFT, communication line protocol, numerical control and peripheral interface adaptors.

It's not MY fault

Micro-diagnostics can verify design integrity and aid fault detection and isolation in the field. Since diagnosis occurs at the primitive function (micro) level, a higher resolution of fault detection is inherent than with macrodiagnostics. Failures may be traced to specific cards or components in a shorter time period than would be possible using conventional macro-instruction level diagnostics. A specific function is tested by each microdiagnostic instruction, whereas a macro-level instruction tests several functions.

As an example, consider communications between a CPU and memory. In the event of failure, macro-level diagnostics could not ascertain the functional status of the memory or CPU. On the other hand, microdiagnostics could check individual data paths, buses and registers within the CPU independent of the memory, providing positive fault detection. **Fig. 1** is a microdiagnostic

routine used to debug the IMP micro-instruction set.

A writable-control-store (WCS) provides the ability to generate new micro-instructions in real time. Thus, the system's response to external stimuli can be optimized. With some hardware redundancy, this feature can bypass defective units in case of failure. Processing can continue with only a slight amount of overall throughput degradation by dynamically re-assigning system resources.

Another use of the writable-control-store is microprogram paging. Microroutines that are frequently executed, but not used together, can be overlaid one upon another in the same physical locations of the writable-control-store. The entire set of microprograms could be contained in ROM or pROM with an associatively

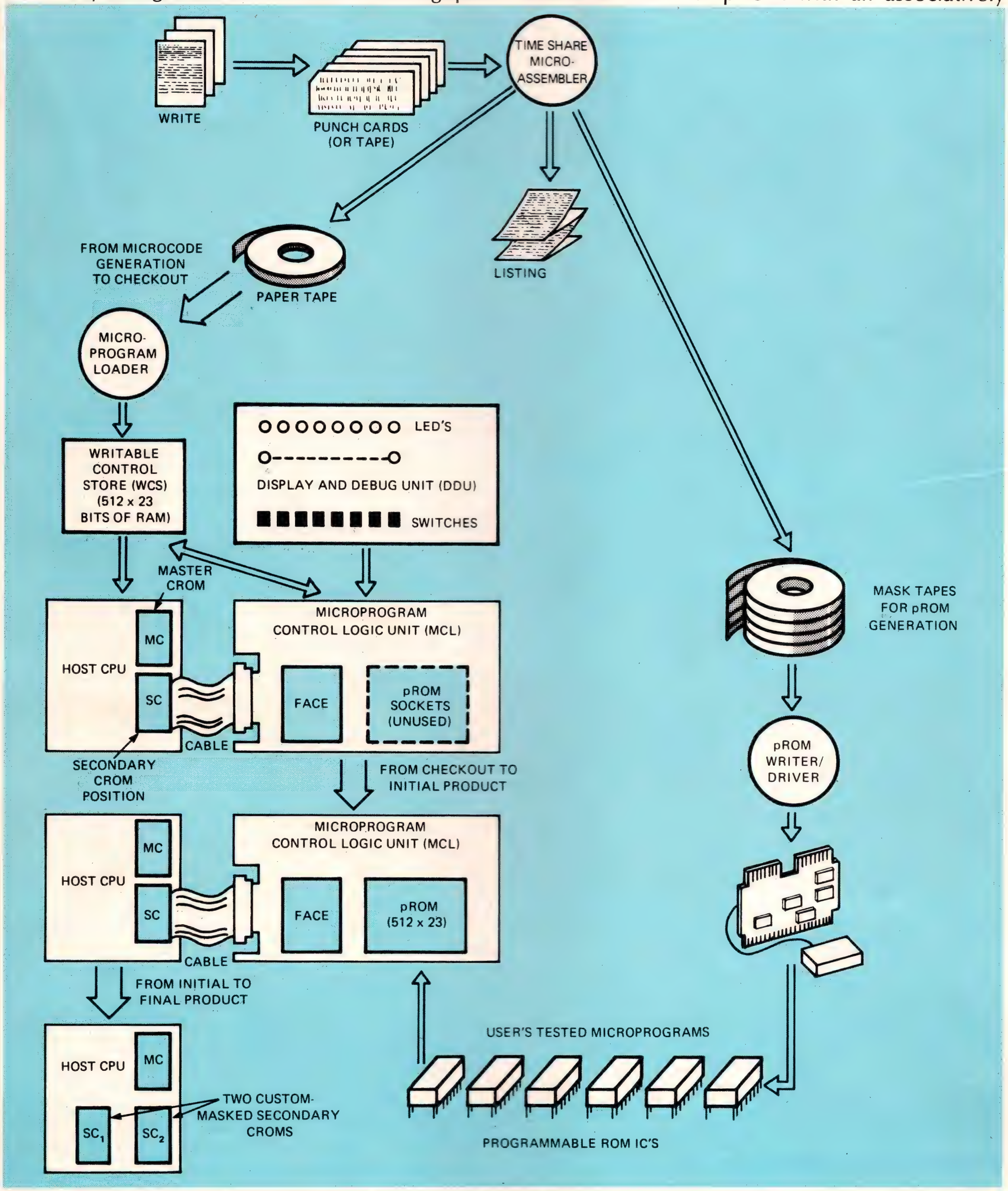

Fig. 2—Augmenting a standard instruction set with special-purpose (customized) instructions proceeds as shown. Debugged and tested object microcode is stored in pROM's on the MCL unit for pre-production systems. In final product, custom mask-programmed CROM's implement the unique instruction set.

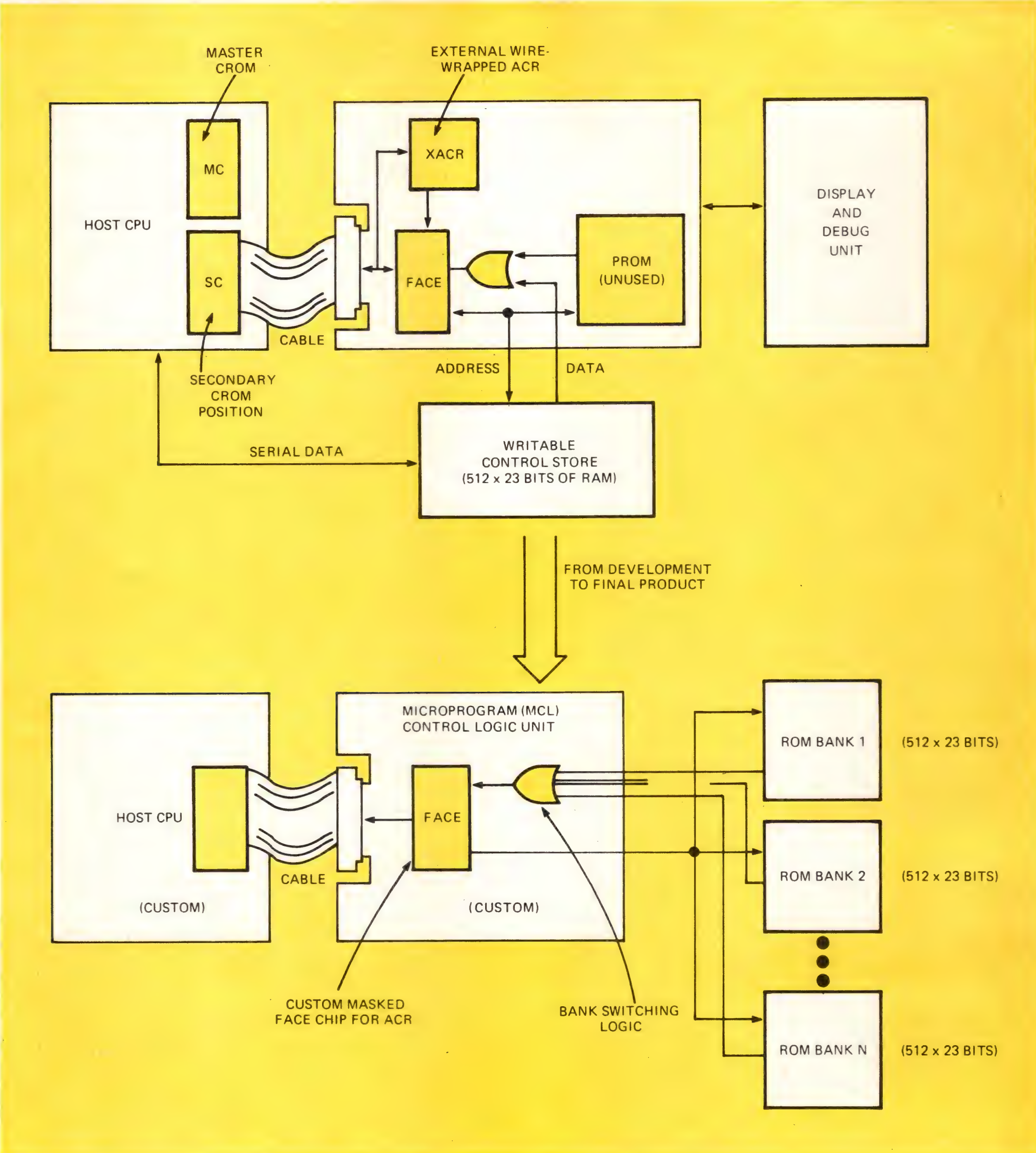

Fig. 3—For larger custom microprograms, flexible FACE chips and WCS units are used. Additional user-defined op-code mapping is provided by the XACR. Tested microprograms, stored in ROM's, are multiplexed into system by MCL on a dynamic demand basis through ROM bank switching.

addressed stack serving as a paging directory for address mapping. This concept is analogous to virtual memory systems on larger computers, in that microprograms larger than the actual control storage capacity can be executed.

Eliminating software simulation

Development and debug of custom IMP microprograms previously have been restricted to two methods: high-level language simulation that is costly and often incomplete, and TTL emulation of the entire MOS chip set that is expensive and complex. If a flexible hardware development system were available, it could eliminate the software simulation stage and speed the whole process of custom microprocessor development.

Designed with this goal in mind, National Semiconductor's Microprogram Development System is partitioned into three segments: a Microprogram Control Logic (MCL) board, a

Writable-Control-Store element and a Display-and-Debug Unit (DDU). Of the three, only the first is required to implement an independent control unit for IMP microprocessors.

The MCL unit is based on a FACE chip that is functionally identical to the CROM, but has buffering for external control memory. Optional, on-board, fusible link pROM's (512 23-bit words) may be included to store the user's microprogram. ROM inhibit logic enables memory bank switching if so desired by the user.

As in many microprogrammed processors, a part of the control element transforms or maps op codes into microroutine start addresses. In the CROM and FACE chips, an address control ROM performs this function. The FACE comes selectively masked to either recognize standard op codes, or "blanked," allowing ACR implementation in an external logic array. In the MCL unit, space is set aside on the pc board for a wire-wrapped logic array that can implement the user's opcode definitions.

The WCS is made up of 512 words by 23 bits of high-speed, bipolar, semiconductor read/write memory. Loading and examining the WCS memory is via a serial handshaking interface, enabling a universal I/O scheme regardless of the configuration of the host system. Serial transmission to the read/write control memory for loading purposes is not a considerable drawback in a development system, since control memory rarely is modified. Users wishing to have a dynamic control store in their end system may design a parallel interface between the host and WCS.

Use DDU, not DDT, to debug it

The Display-and-Debug unit traps, latches and displays the control signals resulting from the user's microprogram at specified times. Switches and LED's on the board provide a simple and convenient man-machine interface and enable the detection and correction of microcoding errors in minimum time.

To minimize the overhead of a user's development project, MDS operates within the host environment either as a secondary control element or as the master controller. Alternately, it can be nonexistent as far as the host is concerned. In this manner, the host system, utilizing a standard CROM as the master, can load the WCS using proven instructions in the master CROM.

Since some users implementing their own op codes and instruction sets may possibly overlap the host's master CROM micro-instruction address space, controller-inhibit logic is provided. It can either manually or dynamically disable the host CROM or the FACE chip.

For example, if the CPU executes a control store loading program, the logic inhibits an enable-control pulse from reaching the FACE chip. This serves to effectively disable FACE while the host CROM is the master controller.

When loading is completed, an instruction (either macro or micro) might be executed to restore the enable-control communication. The next successive macro-instruction may be executed by FACE, which may in turn isolate itself from the host CROM.

I'd rather do it myself

Progressions of two types of user developed microprogrammed microprocessors can be illustrated. **Fig. 2** shows a system in which the user augments a standard instruction set with special-purpose instructions of his own design. The microprogram is written in a symbolic language and assembled on a time-share facility. The resulting object microcode is loaded into main memory and then into the WCS via a microprogram loader. It is debugged and tested using the DDU. The tested microprogram may be stored more permanently in fusible-link pROM's on the MCL unit. These pROM's then are used in a test-bed environment or in pre-production systems. In the final product, the tested, proven object microcode generates a custom mask-programmed CROM. This results in a system that merely utilizes one or more additional CROM's to implement the custom instruction set.

In **Fig. 3,** the development configuration is the same as before, with the addition of user-defined op-code mapping provided by an externally wire-wrapped Address Control ROM (ACR). This system utilizes several pages or banks of microprogram storage that are developed and debugged individually. Tested microprograms are stored in 512-word by 23-bit ROM circuits. These circuits are multiplexed into the system on a dynamic demand basis through ROM bank switching. The resulting configuration uses the more flexible FACE chip and writable-control-store to execute a much larger microprogram than would be possible with custom CROM's.

Looking forward

Microprocessors will continue to gain popularity in the OEM market only as long as system flexibility lends itself to ease of development and implementation. Equipment such as the Microprogram Control Logic unit gives even low volume users the versatility and economic justification to perform their tasks optimally.

Because of this resultant system flexibility, rigid hardware or software design constraints cease to exist. Expansion or functional changes to avoid obsolescence can be made through new micro-

instructions with a minimum impact on existing software.

Ultimately, the most efficient processor for a given application can be designed in a straightforward manner using a microprogrammable building-block microprocessor architecture. □

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Author's biography

Alan J. Weissberger, microprocessor applications engineer at National Semiconductor Corp., Santa Clara, CA, has a challenging job: the development of new microprocessor applications, with emphasis on hardware/software interfaces. Before travelling west, he received his BS in Math from SUNY at Stony Brook and his MSEE at Northeastern University. A member of the IEEE and its Computer Society, Al relaxes with an interesting variety of hobbies: psychology, astronomy, mountain climbing, running and swimming.

Here are the answers to "Test your PLL IQ"

If you haven't sneaked a look already, it's time to see how well you did in our little quiz.

Back in the days when taking quizzes was a way of life, waiting for the results could be traumatic in some cases. This quiz is not structured to be one of those cases. No pass or fail function is intended. Rather, it is hoped that the quiz will serve as a source of information and education. Score yourself as follows:

Number correct:

12-14	You're right, you know enough.
9-11	You're not quite an expert.
6-8	Go back and check your designs.
0-5	If you're using PLL's, get some help from somebody.

We warned you about multiple answers. The following material should explain away any doubts.

1. The circuit of **Fig. 1** is a double-balanced demodulator. When used as a phase detector, it has a transfer function, for low level signals, described by:

$$\frac{2AV_i}{\pi} \cos\phi$$

where A is gain, V_i is the input signal amplitude and ϕ is the phase error between the reference frequency and input signal. Plotting the formula for a constant amplitude input signal will yield the transfer function shown as d.

The exclusive-OR gate of **Fig. 2** has the characteristic shown in c. This transfer function can also be obtained from the double-balanced demodulator when the input amplitude is large enough to exceed the linear range of the circuit.

When used as a phase detector, the asynchronous J-K flip-flop of **Fig. 3** has the transfer function shown as b.

The circuit of **Fig. 4** is designed specifically to perform the frequency/phase detection function, and has the transfer function shown in a. Of the four circuits shown, it is the only one that is frequency sensitive and not prone to false locking.

The double-balanced demodulator and the exclusive-OR gate require a 50% duty cycle on the input waveform—a serious handicap in synthesizer applications. The circuits of **Fig. 3** and **4** are edge sensitive, and the input waveform duty cycle is unimportant.

At lock, the phase relation of the input signals for the four phase detectors are, in the order shown, 90°, 90°, 180° and 0°.

2. Any phase detector that is not frequency sensitive, such as the exclusive-OR, is prone to false locking. In PLL applications, false lock is a serious failing because the VCO must tune over a relatively wide frequency range.

In any application using programmable counters, the requirement for 50% duty cycle on the input waveform is a disadvantage. The output from the counters is typically a very narrow pulse, with a period equal to that of the reference frequency. If the exclusive-OR is used as the phase detector, the programmable counters must be followed by a fixed divide by 2 network. This requires dividing the desired reference frequency by the same factor. Severe reduction in capture

CORRECT ANSWERS

1. 1 - d, 2 - c, 3 - b, 4 - a
2. b, d, g
3. e
4. b
5. b
6. b
7. d
8. b
9. d
10. a - 1, b - 4, c - 3, d - 2, e - 1
11. e
12. c
13. b
14. a

range, and phase detector gain, results if harmonic locking is attempted.

At lock, the output of the exclusive-OR gate is a squarewave, whose frequency is twice that of the reference. The high energy content of this signal requires considerable filtering to obtain an acceptable output from the VCO.

Although the exclusive-OR requires specific input levels, this is not considered a disadvantage. The exclusive-OR function exists in all logic families manufactured, to interface with any type of counter used.

3. The circuit used in this example is phase detector 1 of the MC4044. It exhibits all the characteristics listed. In most phase detectors, the output is a squarewave where the difference in duty cycle represents the phase error. The circuit of **Fig. 4** outputs a pulse whose width is equal to the phase error. With zero phase error, the output is a dc level. This feature greatly reduces the requirements of the loop filter.

This phase detector is both phase and frequency sensitive. When used in a loop, the capture range will be limited only by the tuning range of the VCO.

In addition, since the detector is also edge sensitive, the duty cycle of the input waveform is irrelevant. This is an important feature in synthesizer applications, since it allows for direct interfacing with programmable counters.

4. The phase detector gain constant, K_ϕ, relates output error voltage to relative input phase error. K_ϕ may be obtained from the error signal waveform by calculating the average error voltage in terms of phase error.

$$K_\phi = \frac{V_{peak}\,\phi}{\text{period}} = \frac{0.75}{2\pi}\,\phi = 0.12\,\phi \rightarrow 0.12 \text{ volts/radian}$$

5. In this example, the phase detector gain constant is equal to the slope of the transfer function:

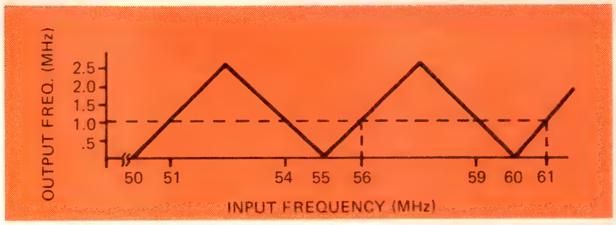
$$K_\phi = \frac{2.25 - 0.75}{2\pi - (-2\pi)} = \frac{1.5}{4\pi} = 0.12 \text{ volts/radian}$$

6. VCO conversion gain has the dimensions of radians/second-volt, and relates output frequency change to input voltage change. It is equal, therefore, to the slope of the transfer function over the range of interest. For our example:

$$K_0 = \frac{(48\text{ MHz} - 12\text{ MHz})\,2\pi}{7.5 - 2}$$

$$= 41.1 \times 10^6 \text{ radians/second-volt}$$

7. For the system of **Fig. 8**, the transfer characteristic at the point of interest is as shown.



It is apparent that an input frequency of 56 MHz gives an output frequency of 1 MHz. The slopes of the transfer function are ±1, and any small change in the input is transmitted to the output on a 1:1 basis. Depending on the slope at the operating point, the gain of the mixer is either +1 or −1.

From the figure, it is apparent that the loop could lock at 51 or 61 MHz, since both give an output frequency of 1 MHz and the slope equals +1. Because the slope is −1, lock will not occur at 54 or 59 MHz. However, the loop could "hang-up" if the VCO is capable of tuning beyond the 54 to 59 MHz range. The interested reader is referred to the "Phase Locked Loop Systems Data Book" by Motorola, where this technique is described in detail.

8. In order to achieve the desired channel spacing, it is necessary to lower the reference frequency by the same factor used for the fixed prescaler.

Loop gain has not been adequately discussed, as it relates to the specific application of frequency synthesizers. If closed loop gain is defined as the output divided by input, then the closed loop gain is simply equal to N. Therefore, the addition of a ÷ P makes the total division equal to NP, and this is the new closed loop gain.

9. The idea of 2-modulus prescaling is to use a low-cost, low-performance counter to control the modulus of a high frequency prescaler and synthesize the ÷ N function. In operation, the prescaler starts in the higher (P+1) modulus, and both the N_p and A counters are enabled. Each cycle of the prescaler increments both counters. When the terminal count of the A counter is reached, the prescaler modulus switches to the lower (P) modulus disabling the A counter. Each cycle of the prescaler now increments only the N_p counter. When the terminal count of the N_p counter is reached, the system resets and the cycle repeats.

For a given cycle, the prescaler divides by (P+1) for A times, and by (P) for (N_p−A) times, or,

$$\begin{aligned} N &= (P + 1)\,A + P\,(N_p - A) \\ &= PA + A + PN_p - PA \\ &= N_pP + A \end{aligned}$$

If A exceeds N_p, the system will reach the terminal count of the N_p counter first. The modulus of the prescaler would never change, and erroneous results would be obtained. Theoretically, A may

TABLE 1					
CHARACTERISTIC	ORIGINAL CONFIGURATION	1	2	3	4
FREQUENCY	$\frac{1}{2\pi\sqrt{LC_D}}$	$\frac{1}{2\pi\sqrt{L(C_D+C)}}$	$\frac{1}{2\pi\sqrt{LC_D/2}}$	$\frac{1}{2\pi\sqrt{LC_D}}$ $1/C_D + 1/C \approx 1/C_D$	$\frac{1}{2\pi\sqrt{LC_D(V=0)}}$
TUNING RANGE f_{MAX}/f_{MIN}	$[C_{D(MAX)}/C_{D(MIN)}]^{1/2}$	$[(C_{D(MAX)}+C)/C_{D(MIN)}]^{1/2}$	$[C_{D(MAX)}/C_{D(MIN)}]^{1/2}$	$[C_{D(MAX)}/C_{D(MIN)})]^{1/2}$ $1/C_D + 1/C \approx 1/C_D$	THIS CIRCUIT WILL NOT TUNE BECAUSE NO DC BIAS PATH EXISTS FOR TUNING DIODES
CONVERSION GAIN, K_D	$\left(\frac{1}{LC_{D(MAX)}}\right)^{1/2} \bullet \left[\left(\frac{C_{D(MAX)}}{C_{D(MIN)}}\right)^{1/2} - 1\right]$	$\left(\frac{1}{L(C_{D(MAX)}+C)}\right)^{1/2} \bullet \left[\left(\frac{C_{D(MAX)}+C}{C_{D(MIN)}+C}\right)^{1/2} - 1\right]$	$\left[\frac{1}{LC_{D(MAX)}/2}\right]^{1/2} \bullet \left[\left(\frac{C_{D(MAX)}}{C_{D(MIN)}}\right)^{1/2} - 1\right]$	$\left(\frac{1}{LC_{D(MAX)}}\right)^{1/2} \bullet \left[\left(\frac{C_{D(MAX)}}{C_{D(MIN)}}\right)^{1/2} - 1\right]$	

be equal to N_p. However, because of the methods used for system resets, this is generally not the case.

10. The characteristics and formulas for the circuits shown are listed in **Table 1**.

11. The maximum frequency excursion for the system is 1 MHz. For a 40% overshoot, the minimum tuning range of the oscillator will be:

$$\text{T.R.} = \frac{(2 + 1.4)\text{MHz}}{(3 - 1.4)\text{MHz}} = \frac{3.4}{1.6} = 2.13{:}1$$

For an overshoot <40%:

ζ min. = 0.4

For a lock time of 2 msec, and a $\zeta = 0.4$:

$\omega_n t = 7$

$\omega_n = \frac{7}{2}$ msec

or $\omega_n = 3500$ radian/sec

12. Regardless of base mixing, the total division can be calculated from the characteristic equation of programmable down counters. The division is always defined as:

$$N = N_0 + N_1B_{N0} + N_2B_{N0}B_{N1} + N_3B_{N0}B_{N1}B_{N2} + \ldots$$

where N_0 is the least significant digit, and B is the base of the counter denoted by the subscript.

For our example:

$N = N_0 + 5N_1 + 50N_2$

$= 4 + 5(9) + 50(15)$

$N = 799$

13. The output frequency is specified to be 30 MHz. From the VCO characteristics, a 30 MHz output requires an input of 4V. With the amplifier gain equal to 200, the error voltage output necessary from the phase detector will be 4/200 = 0.02V.

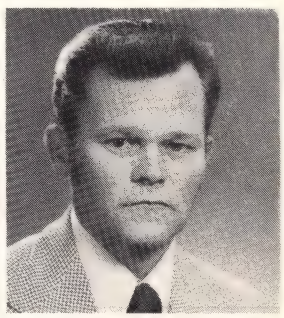
Using the phase detector gain constant, K_ϕ, the phase error will equal:

$$\phi = \frac{0.02}{0.1} = 0.2 \text{ radians}$$

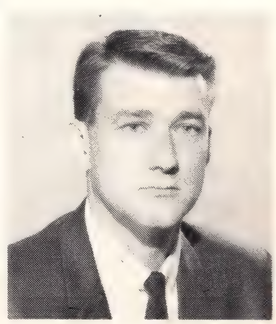
14. Loop gain, K_v, refers to open loop gain, and for the system shown is:

$K_v = K_\phi K_0 A = 200\pi \times 10^6$/sec □

Authors' biographies



L. J. Reed is Project Leader for phase-locked loop design at Motorola Semiconductor Products in Mesa, AZ. In this position, he is responsible for design and development of new IC's for the communications market. He holds a BSEE from the University of Arizona and is working toward his Masters at Arizona State. L. J. has been awarded two patents, and when he is not writing articles for publication, he spends his leisure hours golfing and hunting.



Ron J. Treadway is Design Manager for bipolar-LSI and PPL components. He's been employed at Motorola for nine years. Prior to this, Ron worked at Texas Instruments. He received his BSEE from Bradley and MSEE from Arizona State University. Ron has been granted eight patents, and has six more pending.

EDN DESIGN AWARDS

Digital clock keeps counting even when ac power fails

Samuel I. Green,
McDonnell Douglas Astronautics, St. Louis, MO

This digital clock operates through a power failure with a blanked display at reduced current drain from an internal standby battery. Counting continues via an internal crystal-controlled clock. Thus, this circuit has a significant advantage over ordinary types that must be reset after even brief power outages due to memory volatility.

When the opto-isolator senses supply voltage V_{SS} falling toward battery voltage V_B, the wide-hysteresis Schmitt trigger forces the strobe input to ground. This blanks the display and reduces current drain from 200 to 12 mA. The display goes completely blank when V_{SS} is less than one (GaAs) diode drop above V_B. Therefore, current drain is minimized before the battery begins to supply the total clock current (when V_{SS} approaches one diode drop below V_B). Direct control of the strobe input by the opto-isolator is not recommended because the MOS threshold follows the power supply ripple.

One feature of this design is the ability to unplug the clock and carry it, still operating, to a short-wave receiver for calibration against WWV. The clock can also be thrown into a suitcase for travelling. It will run for days on a 1000 mA-hr

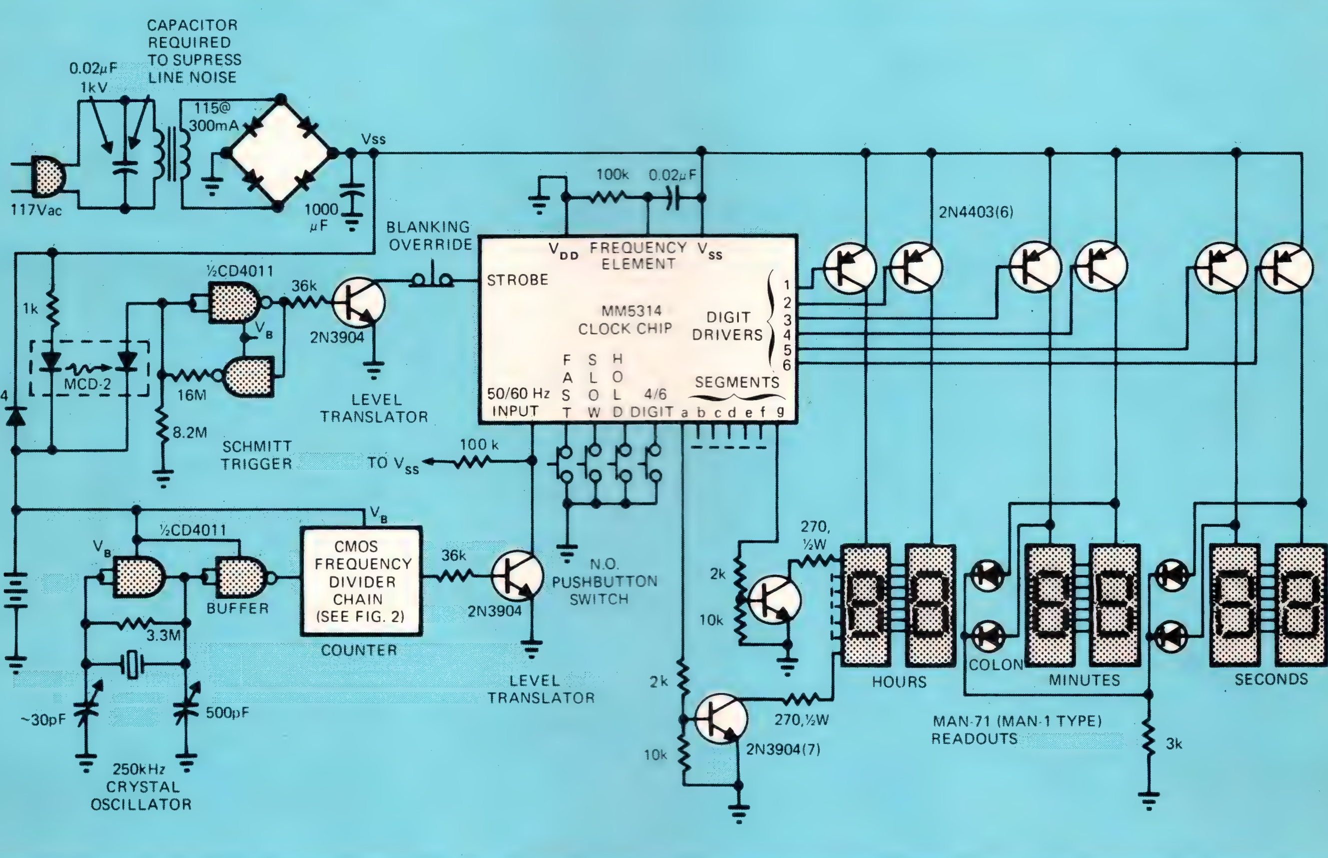


Fig. 1—Now you see it...now you don't. When ac power fails, the Schmitt trigger senses the drop and blanks the display. This reduces drain on standby battery from 200 to 12 mA. However, "blanking override" switch allows momentary time display at expense of increased battery drain.

battery. The "blanking override" pushbutton allows the display to be unblanked for intermittant operation at moderately high battery current.

Colon LED's are operated from the digit strobe lines. They remain lit when the display is blanked, at the expense of 1 mA of battery current. This has the advantage that, when 6-digit operation is selected, the colon between minutes and seconds is activated.

Design of the CMOS counter frequency-divider chain depends on the choice of crystal oscillator frequency. The counters then are chosen to divide to either 50 or 60 Hz, since the MM5314 clock chip will operate with either frequency. The crystal oscillator shown operates at 250 kHz and the divide-by-5000 counter chain is implemented as shown in **Fig. 2**. Note that the CD4017 divides by an integer from 2 to 10 selected by connecting the appropriate output to the reset. The extra gates recommended by RCA are not needed. □

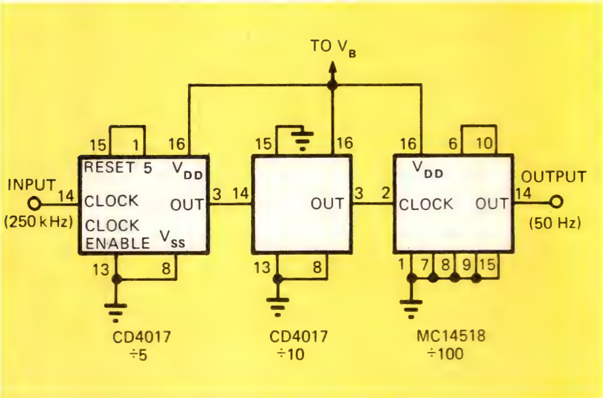


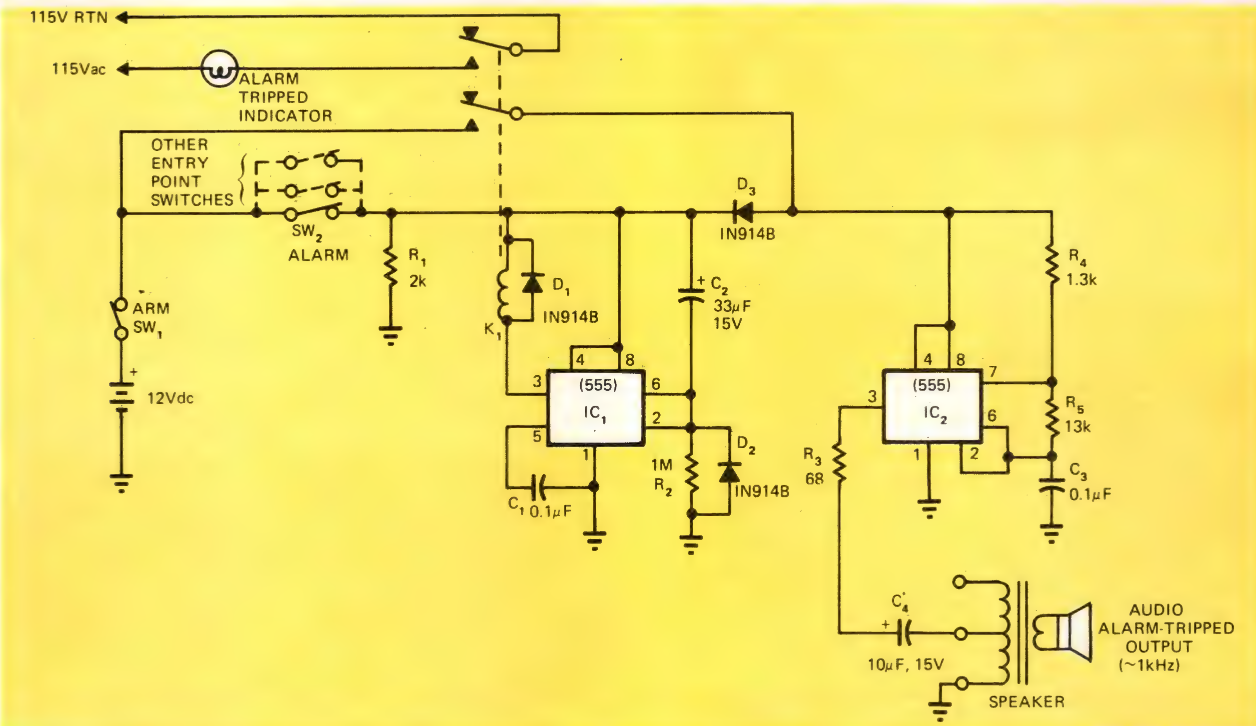
Fig. 2—Since clock chip operates with either 50 or 60 Hz, you have some latitude when designing the CMOS divider chain. This one divides by 5000. CD4017 divides by integers from 2 to 10 by connecting appropriate output to the reset.

To Vote For This Circuit
Circle 160

Burglar alarm is effective, yet simple and inexpensive

James D. Long
Aerojet ElectroSystems Co., Azusa, CA

This device provides an audio and visual alert against improper entry into auto, home, garage, etc. Features include latching after trip (the alarm continues even if the door, window, or other is closed afterward), no standby current from the battery, self-resetting after a predetermined time delay, and high resistance to false alarms other than direct entry. The circuit also will work when



The alarm can't be shut off for a predetermined operate time (10 to 60 sec) even if the trip condition is immediately removed. Circuit draws no standby power from the battery, is self-resetting after a fixed time delay, has high resistance to false alarms other than direct entry, and operates even when ac power fails.

household power fails or in locations where no ac power is available. Many entry points can be covered with a single alarm.

Two 555 timers, a 12V relay, an old speaker from a scrap table-model radio or car radio, a battery and a few switches comprise most of the circuit. The battery can be an old car battery or any 12V unit of much lower capacity. Major current drain is attributed to the coil of K_1, but this occurs only after the alarm is triggered.

Duration of the alarm is set by IC_1 which is connected as a one shot, while IC_2 provides a nearly square-wave drive (exact symmetry is unnecessary) to the speaker transformer. The speaker and transformer should be from a solid-state set where the design is for lower voltage drive. IC_2 is set to operate at about 1 kHz.

The circuit is armed by SW_1, which could be a key switch, but no current drain occurs because the normally-closed alarm switch, SW_2, is open. Other entry points would be covered with switches in parallel with SW_2. If SW_2 is caused to close, perhaps by opening a door, IC_1 is triggered and K_1 activated. This enables both the audio and visual alerts. The light bulb could be connected to the 115V ac supply or driven from the battery.

The circuit is latched through the contacts of K_1. Thus, for the duration of the time delay, further operation of SW_2 makes no difference. If SW_2 is closed at the end of the time delay, K_1 still deactivates and the alarm ceases. D_3 prevents the audio alarm from continuing to operate in this circumstance. If SW_2 is open, the circuit is back to the pretriggered case and can be immediately triggered through its full cycle. When SW_2 is left closed, a charge remains on C_2, and the one shot is not retriggered. This provides the desired effect of terminating the alarm after one cycle. If SW_2 is open at the end of the delay, C_2 is discharged very rapidly through D_2 and R_1, and a new cycle will have the full duration.

C_1 prevents power-line noise from disturbing the operation of IC_1, while D_1 prevents the inductive energy in K_1 from damaging IC_1.

Since the 555 timer can source or sink current, it can easily drive the speaker transformer in a single-ended fashion. C_4 removes the dc component of the drive signal, and R_3 limits the initial charge current to C_4. Many speaker transformers are center tapped for Class B operation. With such speakers, maximum volume is normally obtained by using half the primary, as shown.

Any operate duration between 10 and 60 seconds is considered sufficient for the intended purpose. With the values shown, the operate time is about 12 seconds.

If the device is to be used to protect an automobile, it could be connected to the horn, or an appropriate horn could be used in the general case. In either event, IC_2 and the speaker would be unnecessary. □

To Vote For This Circuit
Circle 161

Long time-constant oscillator uses precision clamps

Lewis Drake
Industrial Nucleonics, Columbus, OH

You can design a stable, long time-constant oscillator if you have a precision clamp circuit. Such a clamp can be constructed easily using the technique shown in **Fig. 1.** When input e_i is below V_c, op amp A_1 saturates in the positive direction. This reverse biases diode D_1, so that $E_0 = e_i$. When e_i increases above V_c, the amplifier output adjusts to keep the maximum value of e_0 at V_c. This assumes, of course, that R_1 is large enough to prevent the saturation of A_1.

By reversing D_1, a lower bound rather than an upper bound is placed on e_0, **(Fig. 2).** The inverting configuration can also be used to provide symmetrical limiting **(Fig. 3).** Here A_3 has been added to eliminate any errors which might be caused due to input loading.

This clamping technique (simulating zener diode action) obviates the need for expensive temperature-stable zeners at various points in a circuit. The clamp point is generally as stable as the reference supply being used, and one supply can service many clamps. The 'knee' of the clamp is square rather than rounded.

The long time-constant oscillator **(Fig. 4)** takes advantage of these features. Basically, this circuit is a standard astable multivibrator modified to function from a single-ended supply. A μA723 provides a 7V reference for clamp amplifiers A_3 and A_4. A_2 provides the oscillator with a reference (V_3) which is half way

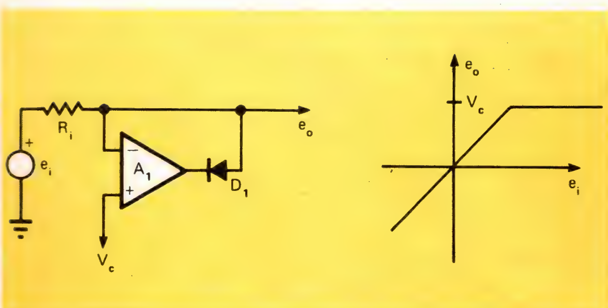


Fig. 1—When e_i is below V_c, A_1 saturates in the positive direction. But when e_i exceeds V_c, A_1 clamps the maximum value of e_0 at V_c.

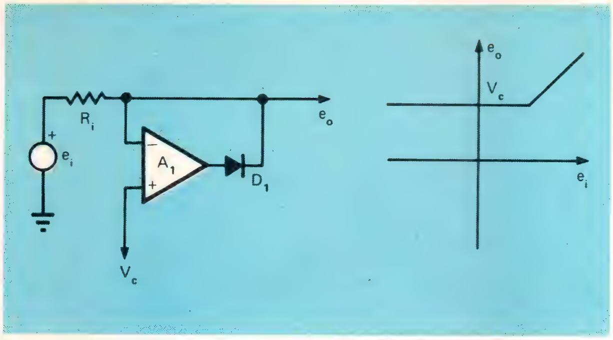


Fig. 2—A lower bound is obtained by reversing D_1. Knee of the clamp is square, rather than rounded.

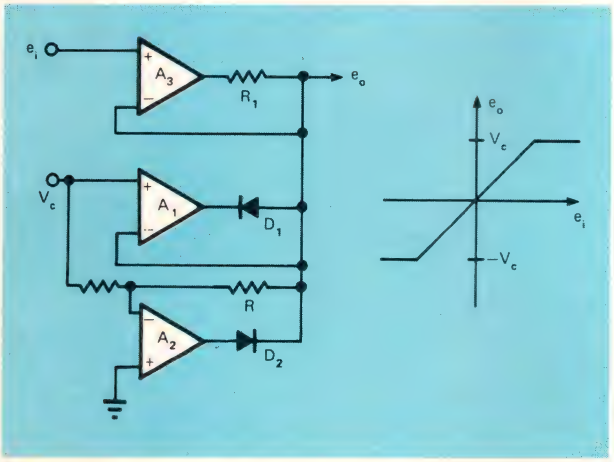


Fig. 3—Symmetrical limiting plus high input impedance are features of this circuit.

between V_1 and V_2.

Stability of the μA723 reference supply is not critical, because a small output change will cause V_1, V_2 and V_3 to vary in the same proportion. Due to this tracking, no steady-state change in the oscillator frequency will result.

Potentiometer R_2 allows the frequency of the oscillator to be adjusted about $\pm 6\%$. The relation describing the period as a function of pot position k_p can be shown to be:

$$T = 1/f = 2R_1C \; 1n \left(\frac{1+k}{1-k}\right)$$

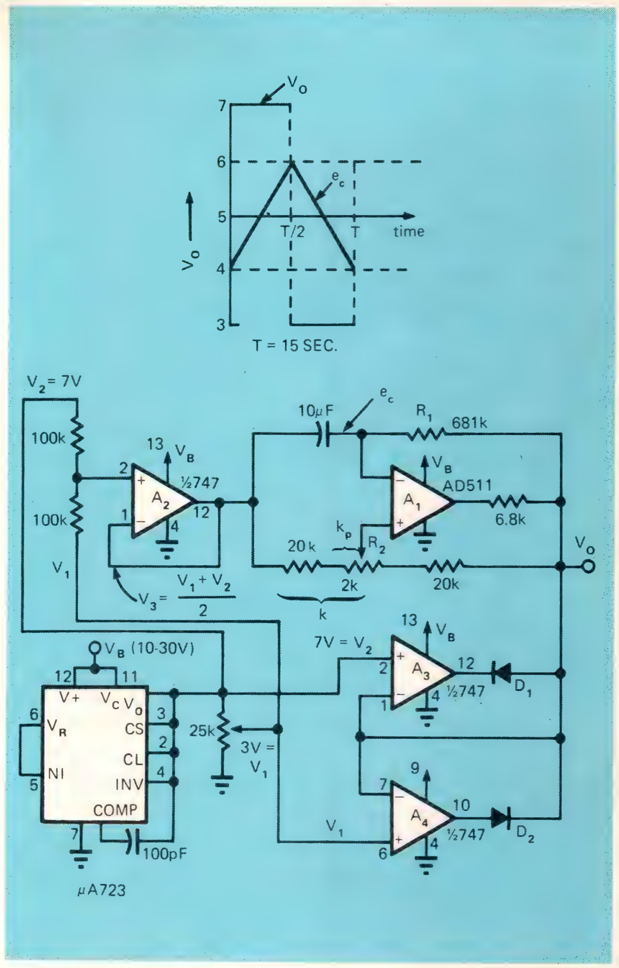


Fig. 4—Period of this oscillator is 15 sec. Clamping technique eliminates the need for expensive high-stability zeners. Steady-state output frequency is unaffected by small changes in output of the μA723, but can be adjusted $\pm 6\%$ by R_2.

$$\text{where } k = \frac{20 + 2k_p}{42} \text{ and } 0 \leq k_p \leq 1$$

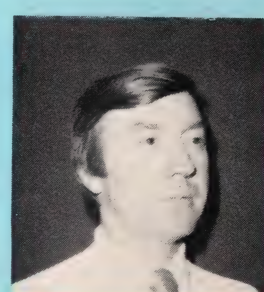
Voltages e_c and V_O, as shown in **Fig. 4,** are for a value $k = k_p = \frac{1}{2}$, and T = 15 sec.

To Vote For This Circuit
Circle 162

Readers have voted:

Eduard J. Richter winner of the May 5, 1974 U. S. Savings Bond Award. His winning circuit is "Op amp makes visual level indicator." Mr. Richter is with Honeywell, St. Petersburg, FL.

Marvin P. Prongue winner of the June 20, 1974 U. S. Savings Bond Award. His winning circuit is "Phase-lock loops test bandpass filters." Mr. Prongue is with McDonnell-Douglas, Titusville, FL.



Circuit card adapter simplifies trouble shooting and breadboarding

PROGRESS IN TEST AND MEASUREMENT

Designed for use with boards containing 22/44 edge contacts on 0.156-in. centers, Vector Electronics' card extender/adapter provides four external test clips ("Klip-Strips") for each contact **(Fig. 1)**. Making up the testing adapter are an 8-in. card extender, Model 3690-11; a single connector adapter, Model TP-1; and the double connector, Model TP-2.

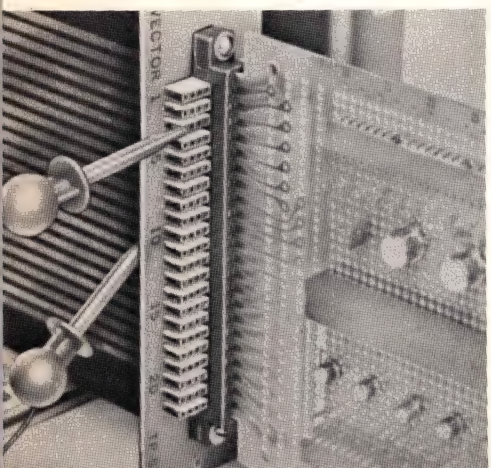


Fig. 1—This novel adapter simplifies testing. Test equipment or components can be connected to the board without soldering.

No soldering required

To test a cage-mounted board, remove the board and plug in the extender (3690-11). Then install the adapter (TP-1 or TP-2) on the extender and plug the original board into the adapter. This arrangement allows measurements and/or insertions of signals at any of the board's pins without probing of or soldering to the board.

An additional feature of the adapter is its ability to connect components or wires to or between the pins without soldering. Wires of 20 to 22 gauge or from 0.015 to 0.032 in. dia. can be inserted directly into the test contacts. Larger wires from 0.04 to 0.08 in. can be inserted into the ends of the test strips. On the bottom side of the adapter are 0.035-in. pins that can be used for connection by probes with small hooks.

Dielectric rating between Klip-Strips is >1000V ac and the clips can handle up to 5A. Contact resistance is <0.001Ω and the capacitance between points is 0.5 pf. Single unit prices are: TP-1 for $16.75, TP-2 for $21 and the 3690-11 for $10.15.

Vector Electronics Co., Inc., 12460 Gladstone Ave., Sylmar, CA 91342. Phone (213)365-9661.

Circle No. 140

IC instrumentation amp provides improved performance at lower cost

PROGRESS IN SEMICONDUCTORS

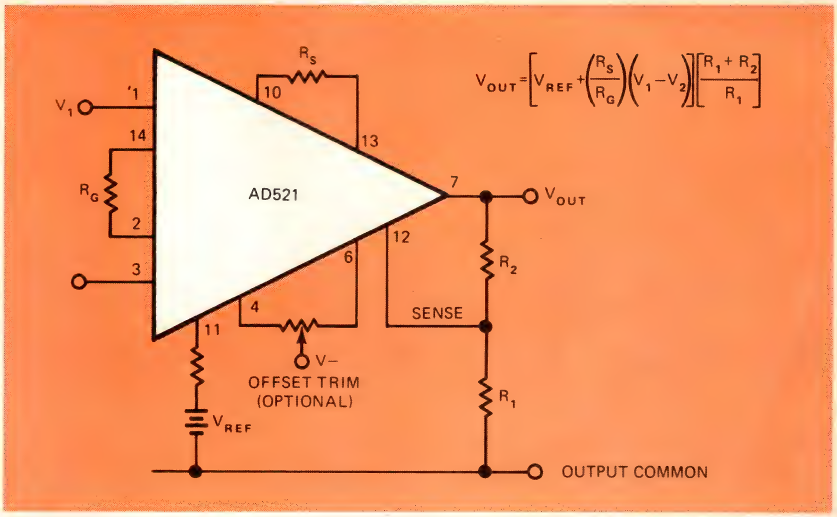
The industry's first second-generation IC instrumentation amplifier has been introduced by Analog Devices Semiconductor. A true instrumentation amplifier, the AD521 is a controlled-gain block with floating differential inputs. Its input/output gain relationship can be programmed accurately from 0.1 to 1000. With prices starting at

Second generation technological advances are responsible for the AD521's high performance.

$8.50 (100's), the AD521 achieves a substantial cost breakthrough over earlier designs.

Performance of the 14-pin hermetically-sealed DIP device compares with many modular instrumentation amplifiers. For example, CMRR is 100 dB min. at a gain of 1000 with a 1 kΩ source imbalance from dc to 60 Hz. Common mode input impedance is a high $6\times10^{10}\Omega \| 3$ pF.

The AD521 has low noise and drift. RTI noise is only 1.5 μV p-p in the 1/f region and 1.2 μV rms over 10 Hz to 10 kHz. Offset voltage drifts for the premium "K" version are <1.5 μV/°C RTI (5 μV/°C max.) and below 50 μV/°C RTO (150 μV/°C max.). For the AD521J, drifts equal 7 μV/°C RTI (15 μV/°C max.) and 150 μV/°C RTO (400 μV/°C max.), respectively.



AD521's gain range can be extended considerably by adding an attenuator in the sense terminal feedback path (as well as adjusting the ratio, R_S/R_G). Actually, the amplifier is functionally complete with the addition of just R_S and R_G.

Increased versatility

This instrumentation amplifier is easy to use. Its inputs are protected whether or not power is applied. Adding only two external resistors, and then changing the value of one of them, varies the gain. Remote sense and reference terminals add versatility.

No slowpoke, the AD521's 3-dB bandwidth exceeds 2 MHz, yielding a 40 MHz gain-bandwidth product. It settles to within 0.1% of its final value to a 30V applied common mode step in under 10 μsec at the worst case gain of 1000.

The AD521J and AD521K versions are specified from 0 to +70°C, and cost $12.75 and $18, respectively (1-24). In 100-999 quantity, these prices drop to $8.50 and $12. A military version, the AD521S, is also available.

For improved reliability, every AD521 is baked for 40 hrs. at +150°C and temperature cycled 10 times from −65 to +150°C. Delivery of all versions is from stock.

Analog Devices, Inc., Box 280, Norwood, MA 02062. Phone (617)329-4700.

Circle No. 141

Bottom-dollar 10-MHz counter runs on 9V transistor battery

PROGRESS IN INSTRUMENTATION

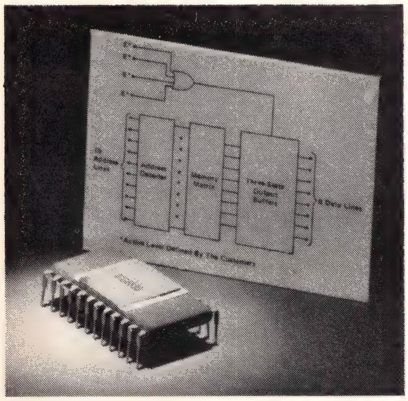
It was sure to come eventually, and now it's here—a battery-powered handful that measures frequencies between 1 Hz and 9.999 MHz, yet costs only $150 complete. Logic Technology's Mark I uses a 0.3-in., 4-digit display in conjunction with a time-base switch. This combination permits the user to make a 6-digit measurement in two steps and with a digit overlapped in the two display readings. For example, 9.876543 MHz reads 9.876 with the time-base switch in "MHz" position and 6.543 plus overflow in the "kHz" position.

Although minimum sensitivity is 250 mV rms, the counter withstands a maximum input voltage of 200V peak. The measurement error from all causes is a quite respectable 50 ppm (0.0005%) max. Gate times are 1 msec or 1 sec.

Either available now, or planned for completion by the end of the year, are a shielded probe, a logic threshold probe and a padded carrying case.

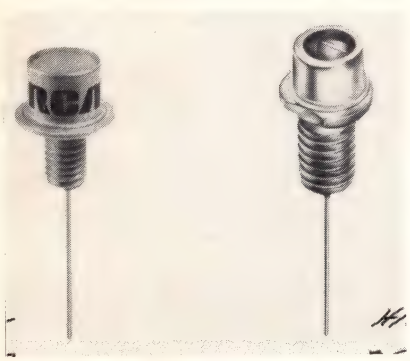
Logic Technology, Inc., 1950 Colony St., Mt. View, CA 94040.

Circle No. 142



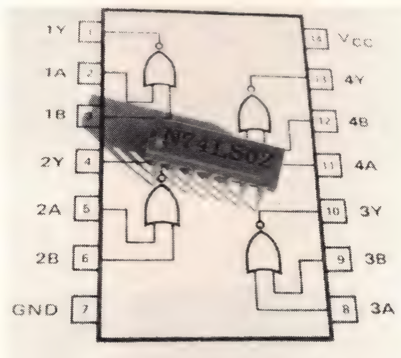
8k ROM OPERATES IN STATIC MODE. This mask-programmable MOS n-channel, silicon-gate device is aimed at storing programs for the MC6800 μP. MCM6830L, a 1024×8-bit ROM, is fully TTL compatible and requires a single 5V supply. The unit operates statically, thus eliminating the need for clock and refresh. Max. access time is 575 nsec over 0 to +70°C; packing is in a 24-pin DIP. $25(1-24). Motorola Inc., Box 20294, Phoenix, AZ 85036. Phone(602)244-3466. **Circle No. 229**

UHF POWER TRANSISTOR HANDLES 40W. Operating in the 450-512 MHz range, SD1089 is internally matched for broadband performance. Designed for use in land mobile 2-way radio, the transistor is available in a 6-lead 1/2-in. diameter flange package. An input impedance transformation is achieved by tuning a MOS capacitor chip, reducing the Q of the input. $29.90(100). Solid State Scientific Inc., Industrial Center, Montgomeryville, PA 18936. Phone(215)855-8400. **Circle No. 230**



LASER DIODE OPERATES AT ROOM TEMPERATURE. Min. power outputs ranging from 1 to 20W at peak drive currents of 10 to 100A are featured in these GaAs single-diode injection lasers. The series is aimed at applications including intrusion alarms and industrial control equipment. They are supplied in coaxial OP-3 and OP-12 packages. Ten units comprise the series. SG2001, $24.35; SG2003, $12.90; SG2012, $36.75. RCA, 415 S. Fifth St., Harrison, NJ 07029. Phone(201)485-3900. **Circle No. 231**

IC DEMODULATOR PROVIDES VERSATILE USE. Acting as a synchronous detector for AM, a quadrature detector for FM and a product detector for SSB or CW, the SL624 can be used to 30 MHz in multimode receivers. The IC also contains a variable-gain audio amp to drive an output stage of several watts. Operating from 9 to 12V, it requires 20 mA at 12V and is packaged in a 16-pin ceramic DIP. $4.44(100♠). Plessey Semiconductors, 1674 McGaw Ave., Santa Ana, CA 92705. Phone(714)540-9979. **Circle No. 232**



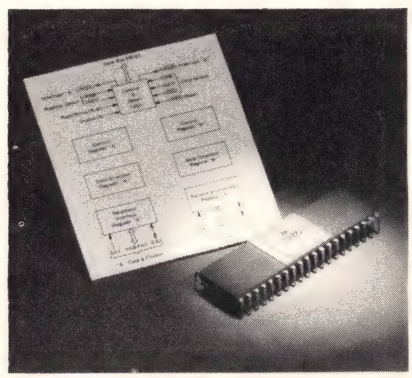
positive logic: $Y = \overline{A+B}$

SPEEDY NOR GATES ARE STINGY WITH POWER. These high-speed positive NOR gates are optimized for power consumption and speed. Propagation time is typ. 10 nsec with a 15 pF load, while power dissipation is 2.75 mW/gate at a duty cycle of 50%. Two gates have the military temp. range of −55 to +125°C. S54LS02F (quad 2-input) costs $2.10(100); S54LS27F (triple 3-input), $2.20(100). With commercial temp. range of 0 to +70°C, N746S02A is 50¢ (100), N74LS27A, 55¢ (100). Signetics, 811 E. Arques Ave., Sunnyvale, CA 94086. Phone(408)739-7700. **Circle No. 233**

TRANSMITTER/RECEIVER SUBSYSTEM IS TTL COMPATIBLE. Designed to provide the interface for data systems utilizing a serial communication link, these units employ MOS construction. NC2257/2260 transmitter accepts parallel binary data and serially transmits this data. Other features include selectable character length and up to 200 bits/sec. NC2259 receiver accepts serial and transmits parallel data. $9(100). Nitron, 10420 Bubb Rd., Cupertino, CA 95014. Phone(408) 255-7550. **Circle No. 234**

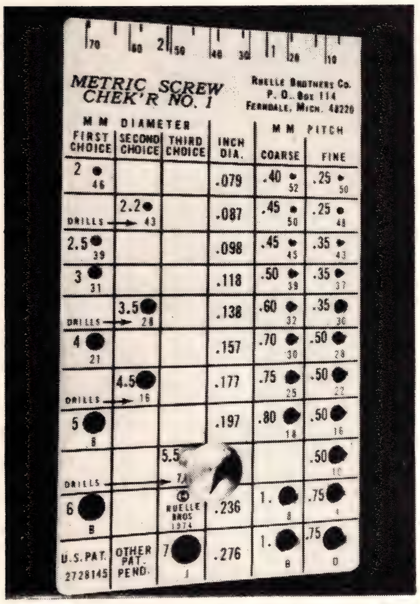
SINGLE CHIP CALCULATOR ARRAY USES MOS. Claimed to be the first chip to provide algebraic problem entry, this unit provides a full range of scientific functions. Included in the array are a 13,000-bit ROM providing 1000 words of storage, together with 8 data storage registers. Logic for control, timing, arithmetic computation and display has been minimized. MPS 2529-001, 002, 003 provide 20, 35 or 40 keys, respectively. $17.50(250k or greater). MOS Technology Inc., 950 Rittenhouse Rd., Norristown, PA 19401. Phone(215)666-7950. **Circle No. 237**

CMOS NOR GATES ARE ALMOST POWERLESS. Dissipating 10 nW, the 4-gate series are constructed with p- and n-channel enhancement-type MOS transistors. Input resistance is $>10^{12}\Omega$ and input current is <10 pA. Each of the four devices—dual 3-input NOR with inverter, quad 2-input NOR, dual 4-input NOR and triple 3-input NOR—costs 47¢(1000). Signetics, 811 E. Arques Ave., Sunnyvale, CA 94086. Phone(408)739-7700. **Circle No. 235**



ARTICULATE INTERFACE WORKS WITH μP. Programmed during system initialization, the Peripheral Interface Unit (PIA) provides a means of interfacing equipment to the MC6800 μP. Data flows between the MPU and PIA by means of an 8-bit bi-directional bus. Data transfer between the PIA and a peripheral occurs on 16 I/O lines. I/O programming is accomplished by the MPU, by means of 2 data direction registers in the PIA. 40-pin ceramic DIP, MC6820 PIA $28(1-24). Motorola Inc., Semiconductor Product Div., Box 20924. Phoenix, AZ 85036. Phone(602)244-6900. **Circle No. 236**

DIP'S WITH TWO 0.5-IN. LED DIGITS ARE END STACKABLE. Two types—the DL-727 with two 7-segment digits plus decimal points, and the DL-721 with ± sign and a "1" preceeding one 7-segment digit—are available. Luminous intensity is 5 mcd at 20 mA/segment, and light pipes spread the illumination evenly. $4.70/2-digit package (1000). Litronix, Inc., 19000 Homestead Rd., Cupertino, CA 95014. Phone(408)257-7910. **Circle No. 175**



METRIC SCREW CHECKERS MAKE IDENTIFICATION EASY. The tools tell metric screw size, thread pitch, diameter in thousandths of an inch, clearance drill size, tap drill size, length in millimeters and inches, and ISO preference rating for all metric machine screws from 2 mm through 14 mm. METRIC CHEK'R #1 covers from 2 to 7 mm and sells for $5.95. METRIC CHEK'R #2 covers from 8 to 14 mm and sells for $6.95. Ruelle Brothers Co., Box 114, Ferndale, MI 48220. Phone(313)674-0119. **Circle No. 176**

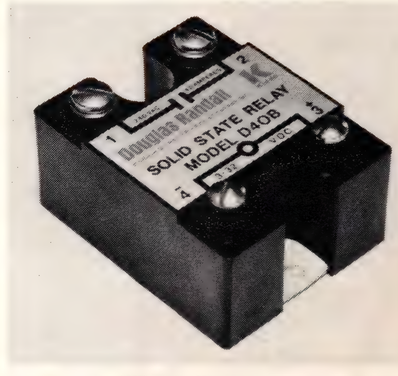
EMI/RFI LINE FILTERS MEET INTERNATIONAL SPECS. These filters are recognized under the Components Program of the U.L. (File No. E49253) and are designed in accordance with the I.E.C., V.D.E., C.S.A., and the proposed ASA specs. Filters are available with current ratings from 1 thru 6A at 125/250V, 0-60 Hz. Only 1.6×1.6×0.81 in., they withstand a dielectric strength test of 2100V dc. The Potter Co., Div. of Pemcor, Inc., Box 337, N. Highway 51, Wesson, MS 39191. Phone(601)643-2216. **Circle No. 177**

SUBMIN. DIPPED SOLID TANTALUMS SPAN 0.1 to 10 μF. Minidip tantalum capacitors are suitable for general filtering, coupling, by-passing and non-critical RC timing uses. Sizes range from 0.175-in. H×0.095-in.D to 0.26-in.H ×0.125-in.D. Tolerance is ±20%; they are rated at 2, 3, 4, 6, 10, 15, 20 or 35V and full rating is to 85°C. They are epoxy sealed, with solder-coated, nickel wire leads. Availability is 6 wks. ARO. Electronic Products Div., Corning Glass Works, Corning, NY 14830. Phone(607)974-8147. **Circle No. 178**

CONNECTORS INTERCONNECT PC BOARDS, CHASSIS AND CABLES. Two-piece miniature connectors of the F series are manufactured to the functional requirements of MIL-C-55302/55, 56, 57, 58, 61, 62, 63 and 64. There are 4 standard body styles (2 female receptacles and 2 male plugs), with short, long dip-solder and solder-cup pins. Fifteen sizes are offered from 10 to 70 pins. Texas Instruments, Inc., Inquiry Answering Service, Mail Station W-1, Attleboro, MA 02703. Phone(617)222-2800. **Circle No. 179**

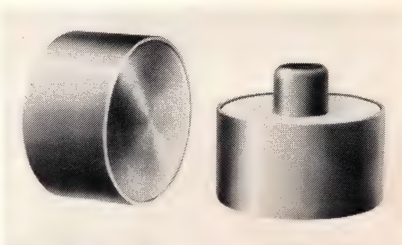
LCD CLOCK FACE HITS 4-IN. HEIGHT. The integrated (1-piece) 43.5C01 is a transmissive-mode dynamic-scattering 3-1/2 digit clock face with 4-in. high characters on one 5×14×1/4-in. display. It is also available in a reflective mode display. Sample, $98; $37(1000). Transparent Conductors Inc., 26 Coromar Dr., Box 549, Goleta, CA 93017. Phone(805)968-3561. **Circle No. 180**

ADJUSTABLE STOPS ADD VERSATILITY TO ROTARY SWITCHES. The adjustable stop feature is inventoried as a standard with either solder-lug or pc-mountable (terminals on one side) termination in the Series 71 (1/2-in. dia) switches. Either version is available in 30° or 36° angles of throw and with a max. of 12 enclosed rotary decks. Grayhill, Inc., 555 Hillgrove Ave., La Grange, IL 60525. Phone(312)354-1040. **Circle No. 181**

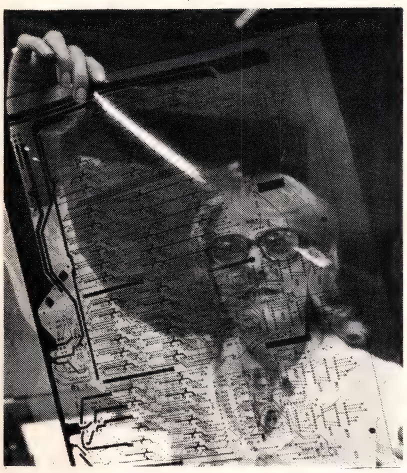


40A MODELS OF OPTO-ISOLATED SS RELAYS ARE OFFERED. Added models will switch 25 or 40A at either 120 or 240V and will handle surge currents to 250 and 400A, respectively. Switching is zero-crossover. Control signals are 3 to 32V dc or 90 to 240V ac, and either Form A (spst-NO) or Form B (spst-NC) is available. Douglas Randall, Div. of Walter Kidde, 6 Pawcatuck Ave., Pawcatuck, CN 02891. Phone(203)599-1750. **Circle No. 182**

LOWPASS FILTERS FEATURE LOW VSWR AND INSERTION LOSS. Tubular filters, available in 13 standard models, provide rejection of >60 dB at 1.4× the passband high frequency. Frequencies from 250 to 1000 MHz are covered by the 1/2-in. dia. models designated 1L. Their power-handling capacity exceeds 15W CW. Higher frequencies (from 1500 MHz to 12.4 GHz) are covered by the 2L models, which are 1/4-in. dia. and handle >2W CW. From $50 to $72. Cirqtel, 10504 Wheatley St., Kensington, MD 20795. Phone(301)946-1800. **Circle No. 183**



ONE-IN. ULTRASONIC AIR TRANSDUCER FITS MANY NEEDS. Model 70100 offers an extremely sensitive, yet low cost device for the transmission and reception of ultrasound in air. Some suggested applications are in intrusion alarm systems, bin and liquid-level measuring devices, pest repellents, proximity detectors and remote-control devices. Linden Laboratories, Inc., Box 920, State College, PA 16801. Phone(814)355-5491. **Circle No. 184**



PROTOTYPE CIRCUIT BOARDS TAKE ADVANTAGE OF PHOTO-RESIST. Although programmed for drilling by computer, these are made using the photo-resist method of image transfer instead of silk screening. Once the prototypes have been approved for high-volume production, the computer tapes already on hand are used to duplicate the original circuit layout. Solid State Circuits, Inc., 616 Boonville, Springfield, MO 65806. Phone(417)869-4678. **Circle No. 185**

STRONG AXIAL LEADS ENHANCE CERAMIC CAPACITORS. Blue Dart™ capacitors with conformal coating are intended for automatic insertion. Two sizes cover the range from 10 pF to 0.12 μF. Three styles are available—general-purpose, X7R and COG (NPO). General-purpose units are rated for 25, 50 and 100V dc, while X7R and COG (NPO) devices have 50, 100 and 200V dc ratings. Emcon, Div. Illinois Tool Works Inc., 11620 Sorrento Valley Rd., San Diego, CA 92121. Phone(714)459-4355. **Circle No. 186**

MINI CODE SWITCH FITS ON CROWDED CIRCUIT BOARDS. This miniature rotary switch measures only 3/8-in. high and is <9/10-in. in diameter. It can be produced to provide decimal, octal, hexadecimal and most other common digital codes and variations. Markings can be provided in any axis on the indicator wheel, with custom legends or characters on the indicator, and in any of 6 colors. The basic switch meets the environmental requirements of MIL-S-22710. Janco Corp., 3111 Winona Ave., Burbank, CA 91504. Phone(213)845-7473. **Circle No. 187**

LSI ELECTRONICS MINIMIZE PRINTER PARTS. Model 102AL is a 132-column serial impact printer with all its complex logic functions condensed into LSI electronics. Character generation is a 9×7 dot matrix pattern and print speed is 330 cps. The 102AL will produce an original, plus up to 4 clear carbon copies, and the last printed line is visible for immediate reading. $4675. Centronics Data Computer Corp., Hudson, NH 03051. Phone(603)883-0111.

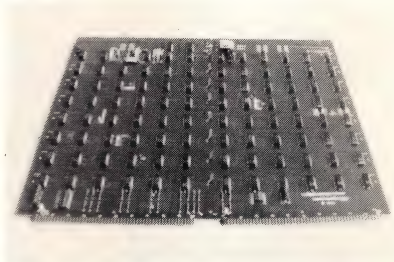
Circle No. 188

PORTABLE DATA LINE MONITOR HANDLES ANY 8-BIT CODE. Dubbed "THE TATTLETALE," Model 485 plugs in between 2 EDP devices. Its CRT displays the data, plus the normally undisplayed control signals that flow between the 2 devices. The user selects either synchronous operation or any 1 of 15 asynchronous baud rates. The panel includes indicators for parity, framing, synch errors and line readiness status. Wt., 10 lbs. $1995. Digi-Log Systems, Inc., Babylon Rd., Horsham, PA 19044. Phone(215)672-0800. **Circle No. 189**

SNAP-ON LABEL HOLDER PROVIDES QUICK TAPE IDENTIFICATION. Scotch brand label holder No. 653 is used with the Scotch brand C-142 and C-143 self-threading tape cartridges. It uses standard size paper labels that slip under a transparent window. When the reel is in use, the label holder can simply be removed and placed into a special clip that is mounted on the drive. 3M Company, Box 33600, St. Paul, MN 55133. Phone(612)733-5755. **Circle No. 190**

COMPUTER GRAPHICS MADE EASIER BY SOFTWARE PACKAGE. The package is EUCLID II (Easily Used Computer Language for Illustrations and Drawings). Commands are written in English, encoded manually, then punched onto tape or cards and fed into the computer. They are translated by the computer program, which is written in FORTRAN 4 and is compatible with all hardware systems. The resulting "machine language" commands the graphic plotter. D-A Computer Services Ltd., Suite 1512, 800 Dorchester Blvd. W., Montreal, Quebec, Canada. Phone(514)871-1580.

Circle No. 191

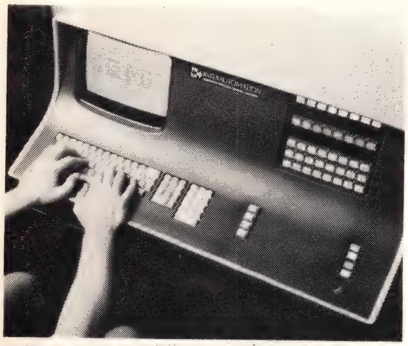


FLOPPY-DISC CONTROLLER REMEMBERS IF DISC IS REMOVED. The FDC102 interfaces a Data General Nova or DCC D-116 to as many as 4 floppy-disc drives. The max. on-line storage capacity is over 1.3M bytes. Standard features are interrupt and noninterrupt drivers, disc formatter program and diagnostic program. The controller uses the DMA data channel of the Nova. It has bootstrap load capability, automatic head unloading and a user-selected device address. $950. MiniComputer Technology, 1901 Old Middlefield Way, Mt. View, CA 94043. Phone(415)965-4567.

Circle No. 192

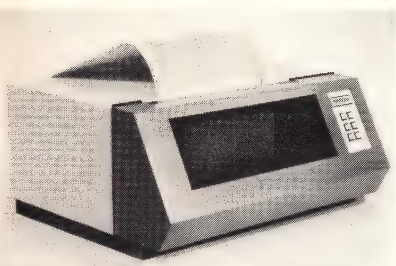
PANELS EASE INTERFACING AND DIAGNOSTIC TESTING. These panels can be used for input/output expansion, for active test stimuli and measurement, or for mounting discrete components that can not be mounted within the card file. They communicate to the card file by means of a 36/54 pin connector mounted at the top of each card. $25(10). Mupac Corporation, 646 Summer St., Brockton, MA 02402. Phone(617)588-6110.

Circle No. 193

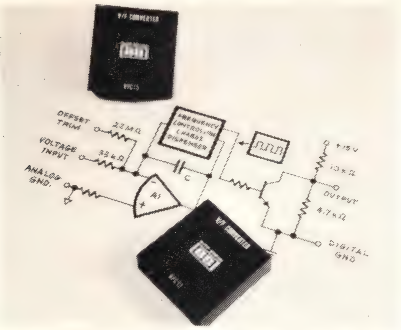


OPERATOR'S CONSOLE INCREASES COMPUTER CONTROL EFFICIENCY. Designed for the IBM System 7, Model 2501 connects to the computer digitally. It permits a dramatic increase in the level of communication without using any of the regular communication channels. The human-engineered 2501 console houses a full alpha-numeric keyboard, CRT display, and lighted pushbutton function switches and indicators. Interautomation, Inc., 2929 Plymouth Rd., Ann Arbor, MI 48105. Phone(313)761-8302. **Circle No. 194**

BIPOLAR MEMORY MODULES ADDED TO ROM SIMULATOR. Eleven ROM/pROM simulation modules have been introduced for the Model 1000A proprietary ROM simulator. Users now have a total of 14 ROM/pROM simulation options, ranging from 256×4 to 1024×4 bits. Implemented with high-speed bipolar devices, the modules specify a max. access time of 100 nsec. $395 to $795, depending on range. Scientific Micro Systems, Inc., 520 Clyde Ave., Mt. View, CA 94043. Phone(415)964-5700. **Circle No. 195**



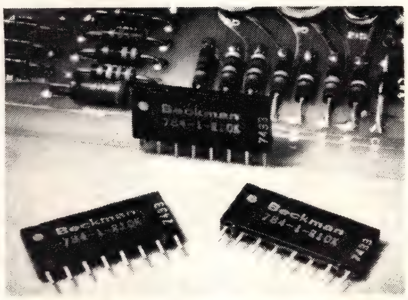
PRINTER DOES DOUBLE WORK AS RELIABLE PLOTTER. The PRINTRONIX 300 is a 300 lpm, multiple-copy matrix printer. It employs uniform density dots laid in overlapping positions to produce a solid type appearance. Font styles and character sets are electronically controlled. This provides a high degree of reliability and ease of change. $3975. Printronix, Inc., 17935 Sky Park Blvd., Irvine, CA 92707. Phone(714)549-8272. **Circle No. 196**



V/F CONVERTERS COMBINE LOW COST WITH ±0.01% ACCURACY. Both the VFC12 and VFC15 have maximum drift of ±50 ppm of F.S. Range (FSR)/°C, and ±5 ppm of FSR/°C offset drift. The VFC12, with output range of dc to 10 kHz, accepts unipolar inputs of 0 to +10V. The VFC15, designed for bipolar or unipolar operation, accepts inputs of 0-20 mA or 0 to +20V. It has an output range of dc to 20 kHz. $57(VFC12), $59(VFC15). Burr-Brown Research Corp., International Airport Industrial Park, Tucson, AZ 85734. Phone(602)294-1431.
Circle No. 197

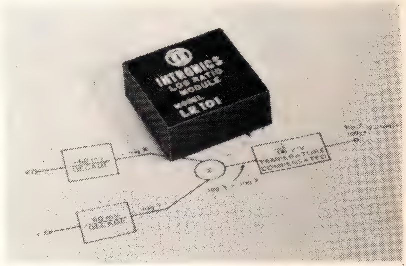
BINARY PROGRAMMABLE FILTERS INCREASE DESIGNERS' OPTIONS. Ten models of 4-pole lowpass Butterworth and Bessel filters provide a wide variety of tuning ranges in the 0.05-Hz to 51.2-kHz freq. spectrum. Typical specs include passband insertion loss of 0.02 dB, 3% cutoff freq. accuracy, 1Ω output impedance, 10^9Ω input impedance and f_c stability of ±0.02%/°C. Attenuation floors of −90 to −100 dB and output noise<75 μV rms are also typical. $81. Frequency Devices, Inc., 25 Locust St., Haverhill, MA 01830. Phone(617)374-0761. **Circle No. 198**

OP-AMP CIRCUIT DESIGN EASED WITH LOW-COST TEST NETWORK. QUICK-OP provides an easy, time saving method of checking a multitude of circuit configurations that use op amps. Completely self contained, it includes a 741C and 40 solderless connector tie points on a function identified panel. Resistors, capacitors and diodes may be quickly inserted for circuit evaluation. ±9V batteries will fit inside the case, or external voltages may be fed in to tie points. $11.95. Hildreth Engineering Co., Box 3, Sunnyvale, CA 94088. Phone(408)245-3279. **Circle No. 199**



SIP RESISTOR NETWORKS SAVE SPACE ON CIRCUIT BOARDS. Series 784-1 contains 7 equal resistors with a common termination at pin 1; Series 784-3 contains 4 equal isolated resistors. Resistor tolerance is ±2%. 15 resistance versions from 100Ω to 22 kΩ are available in each 8-pin network. Individual resistor power rating at 25°C is 0.3W for the 784-1, 0.5W for the 784-3 and total package dissipation equals 2W at 25°C. 65¢ (784-1), 60¢ (784-3). Beckman Instruments, Inc., 2500 Harbor Blvd., Fullerton, CA 92634. Phone(714)871-4848.
Circle No. 200

AMPLIFIERS HAVE WIDE APPLICATION IN RECORDING STUDIOS. AM-27 is a general-purpose audio module, with adjustable gain of 25 to 65 dB, low noise and low distortion. The ABL-27 is designed for cases where bridging a floating or balanced source is necessary. Its gain is adjustable from −7 to +33 dB. The AL-27A has transformer-coupled output, adjustable gain/loss up to ±47 dB and low noise of −125 dBm. Modular Audio Products, 1385 Lakeland Ave., Bohemia, NY 11716. Phone(516)567-9620.
Circle No. 201



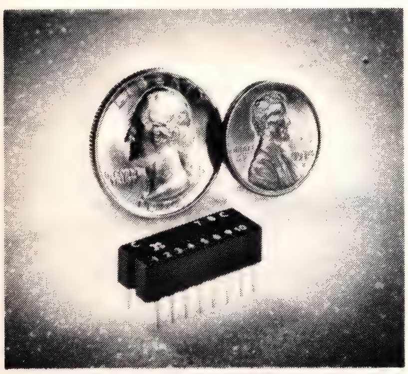
LOG RATIO OPERATORS FEATURE WIDE RANGE, HIGH ACCURACY. Models LR101 and LR102 produce an output voltage proportional to the ratio of two X and Y positive input voltages. For input signals from +10 mV to +10V, total output error is ±15 mV(LR101) and ±10 mV(LR102). Offset temperature drift is only 100 μV/°C from 0 to 70°C. $55(LR101), $70(LR102), with delivery 4 wks. ARO. Intronics, Inc., 57 Chapel St., Newton, MA 02158. Phone(617)332-7350.
Circle No. 202

LOW-NOISE CRYSTAL OSCILLATOR DISPLAYS HIGH STABILITY. Model CO-224 is available at any fixed freq. between 25 and 400 MHz. It provides an output of 20 mW up to 200 MHz, and 7 mW up to 400 MHz. At 1 kHz from carrier, the signal to noise ratio is 130 dB. Aging of better than 1×10^{-8} per day, and temperature stability of ±5×10^{-8} over 0-50°C are achieved by housing the oscillator in a proportionally-controlled oven. Vectron Laboratories, Inc., 121 Water St., Norwalk, CT 06854. Phone(203)853-4433. **Circle No. 203**

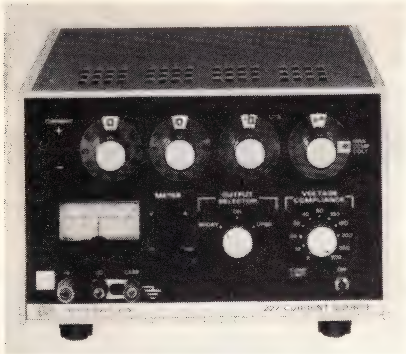
ACOUSTIC DELAY LINE HANDLES MANY TV APPLICATIONS. Model 0.5H has uses for image enhancing, chroma keying, dropout compensation, comb filtering and time-base correction. Its nominal delay is 32 μsec, delay drift ±5 nsec and delay tolerance ±10 nsec. With a center freq. of 30 MHz, it has a 0.2-dB passband of 9 MHz, passband ripple of 0.1 dB and insertion loss of 34 ±1 dB. Input and output impedances are 75Ω and 50Ω, respectively. Walther M. A. Andersen and Assoc., 4 Main St., Ext., Tariffville, CT 06081. Phone(203)658-7666.
Circle No. 204

TRANSISTOR AMPLIFIER COUPLES WIDE BANDWIDTH AND HIGH GAIN. The Model AMT5002 has a frequency range of 500 to 1500 MHz, with gain flatness of ±1 dB. It has minimum gain of 20 dB and noise figure of 5.5 dB max. The amplifier draws 50 mA typ. from a 20V supply and has a max. VSWR of 2:1. Aertech Industries, 825 Stewart Dr., Sunnyvale, CA 94086. Phone(408)732-0880. **Circle No. 205**

PRECISION TIMER DELIVERS ONE PULSE PER MINUTE. Model PT-1 is crystal controlled to provide accuracy of ±0.02%. Using CMOS logic, it draws <10 mA dc. The output pulse is continuously adjustable from 50 to 350 msec. The timer has an auxiliary output of 1 pulse/sec. and operates over the range of −20 to +140°F. Control Interface, Inc., 975 Corbindale, Suite 202, Houston, TX 77024. Phone(713)464-6571. **Circle No. 206**



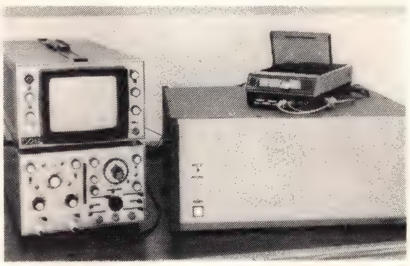
MATRIX DELAY LINE OFFERS 25 POSSIBLE COMBINATIONS. The MDL25 is provided in a 16-pin DIP and is compatible with all current logic families. It is actually 5 delay lines of 10, 8, 4, 2 and 1 nsec in one package. Any delay from 1 to 25 nsec is obtainable, and 50 and 100Ω impedances are available. The unit operates from −55 to +125°C, with a TC of 70 ppm/°C. Rhombus Industries, Inc., 22119 S. Vermont Ave., Torrance, CA 90502. Phone(213)325-7440. **Circle No. 207**



CONSTANT-CURRENT SOURCE DELIVERS UP TO 1.1A. Compliance voltage of the Model 227 is 50V at max. current and 300V at lower currents. The output range spans from 1 μA to 1.1A, and the current level is selected digitally through in-line dials on the panel. $925($1155 with programming option). Keithley Instruments, Inc., 28775 Aurora Rd., Cleveland, OH 44139. Phone(216)248-0400. **Circle No. 208**

MODULAR WORD GENERATOR OPERATES AT BIT RATES TO 50 MHz. The MG-3 contains 1024 bits of random access semiconductor memory, programmable from front-panel controls and via a remote bus. The bits are arranged into an 8-bit×128-word matrix. An 8-bit LED display shows the contents of any word in the matrix. Data output may be either in 8-bit parallel format, or in serial format. $4000. Delivery, 6-8 wks. Tau-tron, Inc., 11 Esquire Rd., North Billerica, MA 01862. Phone(617)667-3874. **Circle No. 209**

1-GHz COMMUNICATIONS COUNTER HAS PLUG-IN IC'S. Model CF-700, with 30 mV rms sensitivity over the temperature range of 0 to 50°C, has a highly readable 8-digit, 0.55-in. Beckman™ display with units annunciators and overflow indication. A collapsible antenna is included, and a crystal-oven option guarantees time-base stability well within the FCC limits. $745. Delivery, 6 wks. ARO. Anadex Instruments Inc., 7833 Haskell Ave., Van Nuys, CA 91406. Phone(213)782-9527. **Circle No. 210**

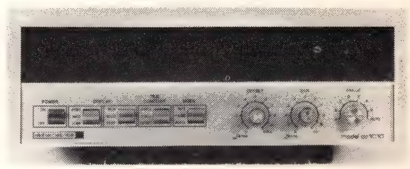


PORTABLE, MULTI-CHANNEL DATA HANDLER EMPLOYS PCM. PCM-100 is a modular data system with 4 channels standard (expandable to 256), higher accuracy than is possible for FM methods (60 dB standard, 72 dB optional) and bandwidths to 1600 Hz. Operation is uncomplicated and data outputs may be slowed down for replay into chart recorders—or sped up for input into computers. From $3000, depending on options. Tetrahedron Assoc. Inc., 7605 Convoy Ct., San Diego, CA 92111. Phone(714)277-2820. **Circle No. 211**

ELAPSED-TIME INDICATOR PROVIDES 6-DIGIT READOUT. The Model 118 delivers 6-digit resolution over 4 elapsed-time ranges, and handles start/stop voltage levels to 150V dc without sensitivity controls. It also has dual range capability (sustained start/stop, or start on pulse "A" and stop on pulse "B"). $265. Delivery, 6 wks. ARO. Thomson Engineering Co., 511 Old Lancaster Pike, Berwyn, PA 19312. Phone(215)647-5658. **Circle No. 212**

CAPABLE MINI-CALCULATOR SELLS FOR $29.95. Model 1100 has addition, subtraction, multiplication and division plus % operation. It also has an automatic constant in all 5 functions, % discount and mark-up, direct %, ratio %, chain discount and mark-up, exponentiation $a^{\pm n}$, and squaring and reciprocal operations. U.S. made, the 1100 comes complete with 9V alkaline battery, case, 90-day warranty and an IB. Melcor Electronics Corp., 1750 New Highway, Farmingdale, NY 11735. Phone(516)694-5570. **Circle No. 213**

MODEM INTERFACE PATCH FITS MANY NEEDS. The MIP-12 provides a means of rearranging interconnections between modems, multiplexers, terminals and computers. It enables an EIA RS-232 interface to be interrupted and transferred to any other interface connected to a patch unit. $65. Spectron Corporation, Church Rd & Roland Ave., Moorestown, NJ 08057. Phone(609)234-5700. **Circle No. 214**



PHOTOMETER/RADIOMETER FEATURES HIGH SENSITIVITY. Model 1010 functions as either a photometer or radiometer and features average and pulse measurements, high sensitivity and stability. It interfaces automatically with any standard or custom light probe—resulting in automatic adjustment of gain factor, exponent range and displayed measurement units to match the selected probe. Readout is 3-1/2 digits, plus exponent. $1920. Alphametrics Ltd., 532 Berry St., Winnipeg, Manitoba, Canada. Phone(204)786-1476. **Circle No. 215**

AUTOMATIC TRANSISTOR ANALYZER REQUIRES NO SETUP. The TF30 is a 2-step tester that first determines a transistor "good" or "bad" to 99.9% reliability. Test leads are connected in any order. For the second step, by rotating the function knob the instrument will distinguish a transistor from a FET, then determine all the critical transistor parameters of Beta, I_{cbo}, G_m, I_{dss}, I_{gss},—plus lead identification and transistor polarity. $240. Sencore, Inc., 3200 Sencore Dr., Sioux Falls, SD 57107. Phone(605)339-0100. **Circle No. 216**

MORE HIGH-FREQUENCY SWITCHING POWER SUPPLIES TAKE A BOW. A 750W unit and 5 150W ones have been added to the JP series. These 20-kHz (inaudible) switchers operate from a selectable input of 115/230, 47-63 Hz, providing 70 to 80% efficiency and 0.1% regulation. Overvoltage and overload protection are standard, and radiated and conducted EMI is minimized by shielding and filtering. $275(150W) and $850(750W). ACDC Electronics Inc., Oceanside Industrial Center, Oceanside, CA 92054. Phone(714)757-1880. **Circle No. 217**

LIMITED-DISTANCE MODEM CUTS COST. Model RTP7420 asynchronous limited-distance modems provide reliable data transmission over twisted-pair lines up to 20,000 ft long. Data rates from 75 to 19.2k baud can be handled without adjustment, and the units are code transparent to any 2-level code. Optical isolators offer complete end-to-end dc isolation and immunity to common-mode noise. Operation can be full duplex. Computer Products, Inc., 1400 NW 70 St., Ft. Lauderdale, FL 33309. Phone(305)974-5500. **Circle No. 218**

LITERATURE

VIBRATION AND SHOCK. This 24-pg. brochure explains how to characterize and measure vibration using amplitude measurement, frequency analysis and motion analysis. Complete features and application suggestions are given for force and acceleration sensors, vibration preamps, real-time frequency analyzers, portable analyzers and tape recorders. B&K Instruments, Inc., 5111 W. 164th St., Cleveland, OH 44142. **Circle No. 219**

ANAEROBIC ADHESIVES. A 6-pg. booklet, #3722, describes the line of 5 anaerobic adhesives for use on screws, nuts, studs, bearings and shafts. Advantages, typical applications and properties are discussed. Standard Pressed Steel Co., Jenkintown, PA 19046.

Circle No. 220

SYNCHROCONVERSION HANDBOOK covers synchro and resolver devices, tracking vs. sampling converters, converter selection criteria, error analysis and applications ideas. More than 100 pgs. of facts, figures, circuit diagrams and theoretical presentations aid the design engineer in solving data conversion problems. Qualified engineers in circuit and systems design may write for a free copy: ILC Data Device Corp., Airport International Plaza, Bohemia, NY 11716.

INQUIRE DIRECT.

COMPUTER SECURITY, employment of computer personnel, software protection, and the ways and means to prevent embezzlement by computer are discussed in this 60-pg. manual. All articles were published in Security World magazine. $3.95. Security World Publishing Co., Inc., 2639 S. La Cienega Blvd., Los Angeles, CA 90034.

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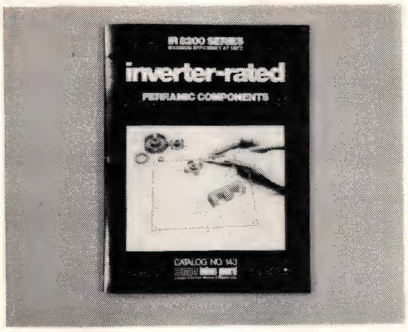


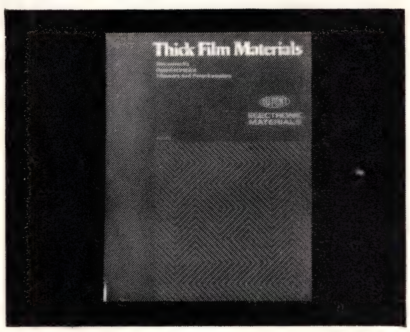
FERRITES. This 38-pg. design guide gives component specs, temperature characteristics and application data for inverter-rated ferramic cores. Extensive circuit performance data and a complete set of design nomographs are included. Indiana General, Keasbey, NJ 08832.

Circle No. 221

MIXERS. Product guide introduces a line of microwave double-balanced mixers. A summary of specs for each model is included, along with prices and outline drawings. Watkins-Johnson Co., 3333 Hillview Ave., Palo Alto, CA 94304.

Circle No. 222

PRECISION GAS-GAP PROTECTORS for transient voltage suppression are detailed in bulletin 6600. The bulletin describes application features, typical circuit arrangements, sources of transients and term definitions. MidCom, Inc., 1650 Tower Blvd., N. Mankato, MN 56001. **Circle No. 223**



THICK-FILM MATERIALS. The 8-pg. catalog, #E-00713, describes microcircuit compositions. These include conductor, resistor and dielectric inks; optoelectronic materials; and resistor and conductor compositions for potentiometers and trimmers. Du Pont Co., Electronic Materials Div., Wilmington, DE 19898. **Circle No. 224**

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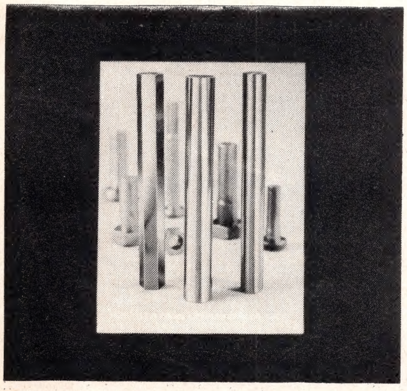


ALLOYS FOR FASTENERS. This publication discusses the alloys specified for fasteners to combat severe service conditions in the marine, chemical/petrochemical, aerospace, electrical and civil engineering industries. Included are alloys from the MONEL ™ nickel-copper series, the INCONEL ™ nickel-chromium series and the INCOLOY ™ nickel-iron-chromium series. Huntington Alloy Products Div., Box 1958, Huntington, WV 25720.

Circle No. 225

PHOTOELECTRIC DEVICES. Catalog P-571 provides 22 pgs. of detailed information on completely self-contained photo-electric sensors, 2-part sensors, and photoelectric system components. It provides detailed specifications, block and wiring diagrams, timing diagrams, schematics and dimension drawings. Warner Electric Brake and Clutch Co., 449 Gardner St., Beloit, WI 53511. **Circle No. 226**

ADC'S. A data sheet describes the ADC-D and ADC-K Series of A/D converters. These converters offer moderate speed and accuracy at a low cost. The data sheet includes application notes, specs., mechanical dimensions, input/output connections and ordering information. Datel Systems, Inc., 1020 Turnpike St., Canton, MA 02021.

Circle No. 227

TUBING PRODUCTS. Catalog T-2 contains detailed descriptions, applications and specifications on 38 tubing products. There are 11 types introduced including 3 in the FIT shrinkable-tubing line. Also featured is a new type of zipper-tubing closure, the Loc-Trac. This UL-recognized component fits short-run or prototype cable needs. Alpha Wire Corp., 711 Lidgerwood Ave., Elizabeth, NJ 07207. **Circle No. 228**

'MARVIN'S MARVELOUS MINI'. This 8-pg. booklet chronicles the misadventures of a not-too-hypothetical engineer named Marvin Hotchkiss after he finally realizes his dream to build a minicomputer. It points up the perils of computerization confronting the OEM original who ventures into Mini-land without a guide. Computer Automation, Inc., 18651 Von Karman, Irvine, CA 92664. **Circle No. 229**

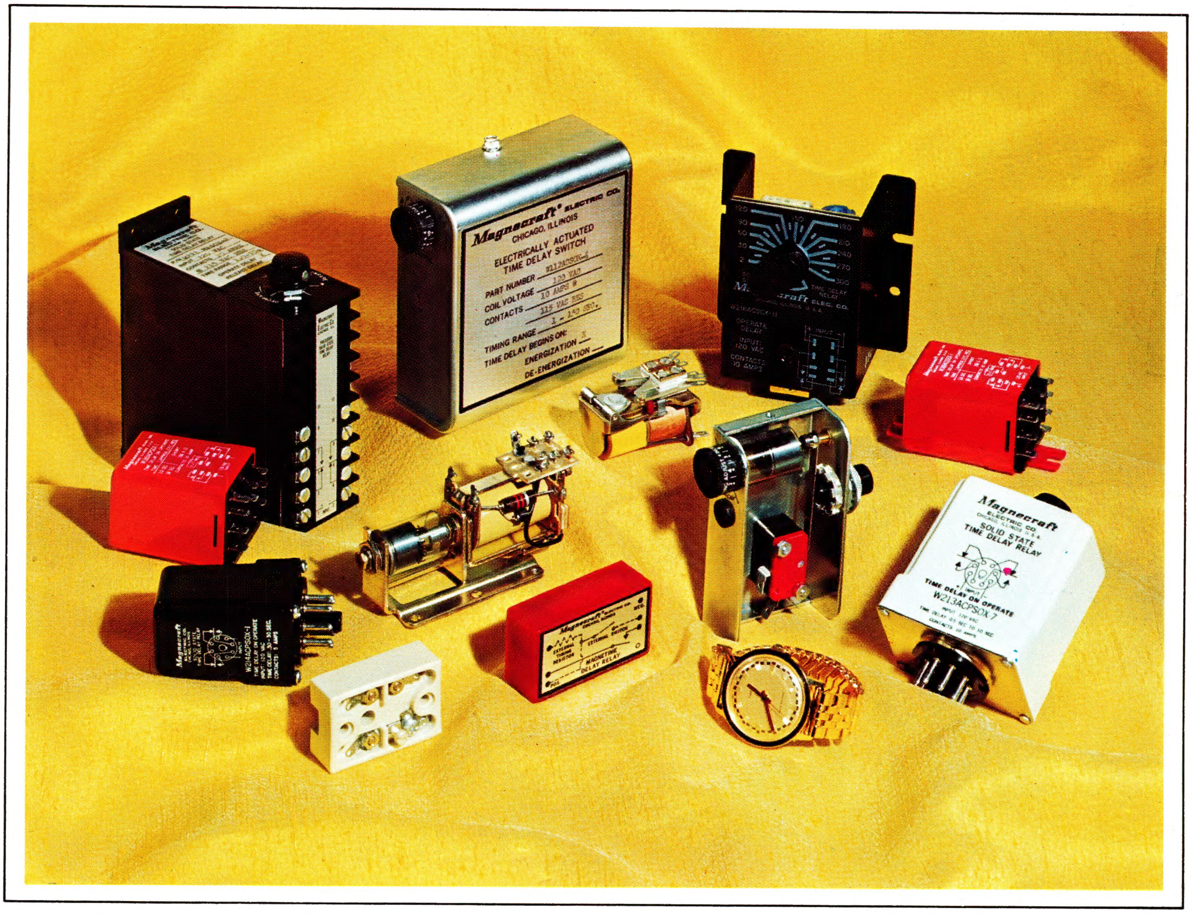
RECORDING INKS. Its cross reference of part numbers, colors and sizes of the recorder inks distributed by all major OEM's makes this 12-pg. bulletin handy for engineers, laboratory, maintenance personnel and purchasing agents. It also discusses the manufacturing and storing precautions necessary to prevent data loss due to ink contamination. Graphic Controls, Inc., 2 Springdale Rd., Cherry Hill, NJ 08003. **Circle No. 230**

ADVERTISERS INDEX

EDN CLASSIFIED ADVERTISING

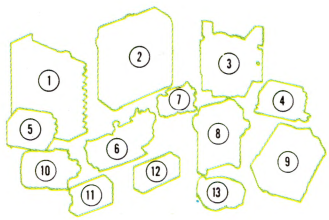
BIG TIMERS

Relays That Can Solve Your Time Delay Problems



Magnecraft's BIG TIMERS come in all shapes, sizes, and timing ranges for your applications. Time delay relays with slow operate or slow release and time repeat accuracy ±1%. Each relay is designed to function with absolute reliability, for long life at lowest cost. Versions offered include: solid state hybrid, copper slug, thermal, air dashpot, telephone type, mercury displacement, and solid state-static output. The photo portrays just some of the endless features, mountings and packaging characteristics available with Magnecraft built-in quality and integrity.

Over 100 different stock time delay relays are available through our nationwide network of distributors. But, if you don't find what you need in stock we will custom build it for you!



1) Air Dashpot Class 112M **2)** Air Dashpot Class 112C **3)** Solid State (Hybrid) Class 218 **4)** Solid State (Hybrid) Class 388 Flange Mount **5)** Solid State (Hybrid) Class 388 Plug-In **6)** Air Dashpot Class 110 **7)** Copper Slug Class 66S **8)** Air Dashpot Class 113C **9)** Solid State (Hybrid) Class 211CP **10)** Solid State (Hybrid) Class 214CP **11)** Thermal Class 150 **12)** Printed Circuit Class 502 **13)** Our Advertising Manager's Watch

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TIME DELAY RELAY CATALOG

To help specify your time delay relay needs, ask for Magnecraft's Seventh Edition of the Time Delay Relay Catalog. It offers suggestions on how to specify, testing procedures, comparisons of the types available, principles of operation and a glossary of terms. This super, 52 page catalog is yours for the asking.

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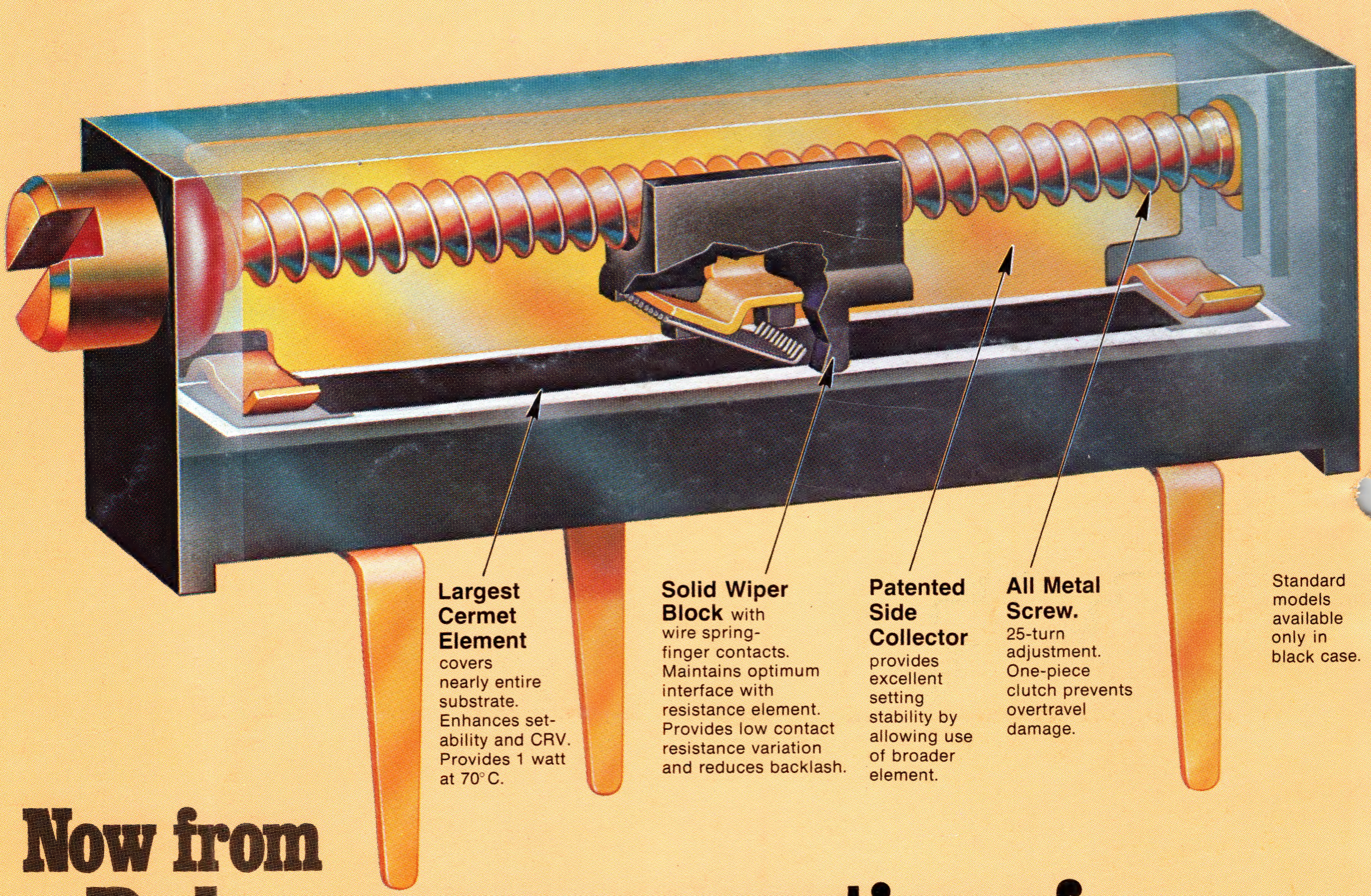

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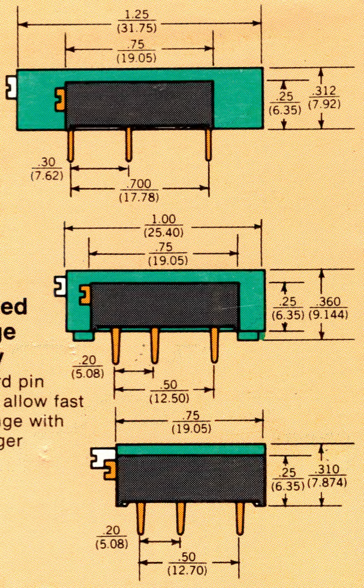

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